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THRESHOLD TEST BAN TREATY AND PEACEFUL NUCLEAR EXPLOSIONS TREATY

HEARINGS

BEFORE THE

COMMITTEE ON FOREIGN RELATIONS UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

JANUARY 13 AND 15, 1987

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THRESHOLD TEST BAN TREATY AND PEACEFUL NUCLEAR EXPLOSIONS TREATY

TUESDAY, JANUARY 13, 1987

U.S. SENATE,
COMMITTEE ON FOREIGN RELATIONS,
Washington, DC.

The committee met at 10:05 a.m. in room SD–419 Dirksen Senate Office Building, Hon. Claiborne Pell (chairman of the committee) presiding.

Present: Senators Pell (presiding), Sarbanes, Zorinsky, Cranston, Kerry, Sanford, Adams, Pressler, Trible and Evans.

The CHAIRMAN. This meeting of the Committee on Foreign Relations will come to order.

First of all, I would like to welcome everyone here, the new members who shortly will be turning up, we hope, and all those who are in the hearing room, to this, the first meeting of this committee in the 100th Congress.

Actually, when all of our Members are aboard, we will find that this is the largest our Committee has been since the 80th Congress 40 years ago. So we are going to be a little bit crowded on the Senate side here.

We will be crowded on the dias until a larger one is constructed and installed. And because of the television cameras being there as well, our plan is to change sides and have the more numerous Democrats on the right where they are not cluttered up by the cameras.

Today, we begin a series of three hearings on the Threshold Test Ban Treaty signed by President Nixon in 1974, and the Peaceful Nuclear Explosions Treaty signed by President Ford in 1976.

This afternoon we will have a closed session with the intelligence community witnesses in Room S–407 of the Capitol. And then our third and final hearing will be with nongovernmental experts on Thursday, January 15.

Our target is to markup the treaties, the instrument of ratification, the recommendation for ratification, on Tuesday, January 20. That is our ambition, following the admonitions of the President to move ahead, and following out our own desires to move ahead.

Whether we achieve that schedule, we will see. It is appropriate, in my view, that we begin this 100th Congress with an arms control issue, for there is nothing more important than adding to the structure of agreements designed to prevent nuclear holocaust.

Last year, as the 99th Congress drew to a close, President Reagan and General Secretary Gorbachev discussed sweeping concepts that would if implemented drastically reduce United States and Soviet nuclear arsenals.

If those goals are to be achieved, parallel efforts are needed to initially limit and then to prohibit the nuclear tests associated with the development of new and more dangerous weapons.

And shortly before the Iceland summit, President Reagan assured the Congress that he would take two important steps toward limiting nuclear testing. I won't read the whole text of his letter or the pertinent paragraphs, but I will read at least two sentences. His exact words were:

> I will still make ratification of these treaties a first order of business for the Congress, with an appropriate reservation to the treaties that would ensure they would not take effect until they are effectively verifiable. I will work with the Senate in drafting this reservation.

It's now been eight years since a United States President concluded an arms control agreement with the Soviet Union. And it's been 24 years since the Senate last gave its advice and consent to a nuclear testing treaty with the Soviets.

This is a sorry, sad record that I hope will end this year.

Today, the committee resumes a process that began 10 years ago when our Committee first considered and actually voted approval of the Threshold Test Ban and Peaceful Nuclear Explosions Treaties, but our Committee never reported them out.

It's my hope that the President's statement of last year will improve the prospects for successful action this time.

I've given the treaties high priority in our Committee; put them as the first item on our agenda; and the Majority Leader has done the same for the Senate as a whole, just as has our President.

The committee must decide whether to report a resolution of ratification on the two treaties. It must also decide what reservation, if any, to attach to the resolution.

And the President has said that he wishes a reservation dealing with verification, and that he would work with the Senate in drafting that reservation.

Following up on that idea, I asked the Committee staff of both parties to work with representatives of the Administration in an effort to develop language that I could put before the Committee for its consideration.

That process has been underway and is still underway. I must be frank in adding, however, that leaks that have not occurred from the Senate side on the text being discussed by the staffs have not been helpful.

Approval of the TTBT and the PNE treaties could play an important role in opening the way to further testing restraints, and in reaching the ultimate goal of a comprehensive test ban.

In fact, if these treaties were intended to be the end of the road in constraining nuclear tests, rather than simply way-stations on the way in that direction, I'm not sure there would be much interest, at least on this side of the aisle, in considering these treaties.

If these treaties are to make the kind of contribution I believe they should make, our Committee must ensure that its action is meaningful. Good faith cooperation on the part of the Administration in bringing the treaties into force will be essential.

I look forward to hearing the views of the Administration witnesses as to how we can best accomplish that. And I would ask the acting ranking minority Member if he has a statement he would care to make.

Senator Pressler.

Senator **PRESSLER**. Thank you very much. I would first of all thank the Chairman for his fine statement and his leadership in this area.

I do think it's very appropriate that we should move forward with these treaties. I think that in the present atmosphere they have a larger role to play, a larger meaning, than just ratifying them.

I am still very hopeful that Ronald Reagan will have a major summit during his Presidency. I have often said that I feel he is in a unique position on the arms control issue, because he could get treaties ratified, as this action we're going through today illustrates.

A key issue, of course, is verification regarding these treaties. And Mr. Chairman, several years ago, I wrote an op-ed that was published in the Washington Post regarding the issue of verification of these treaties. And I would ask unanimous consent to be able to insert that into the record.

The **CHAIRMAN**. Without objection.

[The information referred to appears in the appendix.]

Senator **PRESSLER**. Let me add that I think it is time we deal with these treaties one way or the other. I do support them, but I think that what we are doing could well be a prelude yet in the last two years of Ronald Reagan's presidency to a summit or to a more major arms control agreement. Mr. Kampelman's position has been upgraded and various other encouraging things are happening, despite the problems with Irangate.

I still contend that Ronald Reagan is uniquely positioned to negotiate arms control, as Richard Nixon was positioned to go to China.

He is a man who can get treaties ratified. And these two have been around a long time. I think we would have to say that they probably would not be moved forward at this time, there would be much more opposition to them if the Administration did not support them.

So I compliment the Administration in that area.

At any rate, I ask unanimous consent to submit an additional statement. And I thank the Chairman again for making this our first item of business.

The **CHAIRMAN**. There will be no objection to the insertion of an additional statement, or other statements, on the part of any Senators who wish to have them inserted.

At this time, I welcome hearing from our witnesses. We have with us the Honorable Allen Holmes, Assistant Secretary for Politico-Military Affairs; Dr. James McNally, Deputy Assistant Director, of the Arms Control and Disarmament Agency; the Honorable Robert Barker, Assistant to the Secretary of Defense for Atomic Energy; the Honorable Sylvester Foley, Assistant Secretary for Defense Programs, Department of Energy; and Lt. Gen. Dale Vesser, Director for Strategic Plans and Policy of the Joint Staff.

I must be missing one, because there are five there, and there are six individuals.

I understand General Vesser has General Denson with him, an assistant.

How would you like to start out? I will call on my old friend Mr. Holmes.

STATEMENT OF HON. H. ALLEN HOLMES, ASSISTANT SECRETARY FOR POLITICO-MILITARY AFFAIRS, DEPARTMENT OF STATE

Ambassador HOLMES. Thank you, Mr. Chairman.

I would like to first apologize for my tardiness. We ran into an accident and we were rerouted several blocks.

I welcome this opportunity, Mr. Chairman, to appear before you for the purpose of addressing the Administration's request for the Senate's advice and consent with an appropriate reservation to ratification of the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty.

I am pleased to note that Administration officials and members of the Senate staff have held thorough consultations on this subject, and I appreciate the cooperation of your professional staff.

United States policy, with respect to the broad issue of nuclear testing limitations, has been clear and consistent throughout this Administration. We are committed to the ultimate attainment of a total ban on nuclear testing under appropriate circumstances, a goal that has been endorsed by every President since President Eisenhower.

But for the present, the United States, its allies, and its friends, depend on nuclear weapons for deterrence. So long as we must continue to rely on a secure and credible nuclear deterrent as the ultimate guarantor of peace with freedom, some level of testing will be necessary to ensure the safety, reliability, effectiveness and survivability of our nuclear weapons.

We want to make progress in this area. However, as the President outlined in his letter of last October, we are here today to testify in support of the Administration's approach to nuclear testing limits.

The CHAIRMAN. Excuse me, but as a matter of procedure, without objection, the President's letter will be inserted into the record.

Ambassador HOLMES. Thank you.

[The information referred to appears in the appendix.]

Ambassador HOLMES. The negotiations and support of these treaties represent long and serious efforts by several Administrations. They reflect the considered judgment of several presidents that carefully structured limitations on the nuclear weapons development process, if fully observed by both sides, are positive steps.

In 1974, the United States and the Soviet Union negotiated a Threshold Test Ban Treaty, and in 1976, they signed the Peaceful Nuclear Explosions Treaty.

Neither of these treaties has been subsequently ratified by either the United States or the Soviet Union. Since 1983, the President has sought verification improvements that will enable him to move forward on ratification.

For its part, the Soviet Union has claimed that if the United States would ratify the TTBT and PNET, and implement their verification provisions, our verification and compliance concerns would be promptly resolved.

However, our problems would not be resolved. Large uncertainties would remain. For example, the data to be exchanged on ratification of the TTBT would itself be unverified. Nor would the verification measures in the PNET resolve our concerns about that treaty.

With the necessary verification improvements we seek, we believe these treaties would be in our national interest. The treaties were negotiated as important parts of the United States' longstanding policy of controlling the development and inhibiting the spread of nuclear weapons.

Specifically, these two treaties, which we have scrupulously observed for over a decade, prohibit larger yield nuclear explosions, such as tests once carried out by the Soviets, at levels 15 to 20 times greater than 150 kilotons.

This restriction imposes a significant qualitative limit on one aspect of nuclear weapons development competition.

Under Secretary of State for Political Affairs Philip Habib testified before this Committee about ten years ago. He said, and I quote: I believe the political benefits which can accrue to us by the ratification of these treaties are as significant as the contributions which they make to the control of nuclear weapons, unquote.

Formal agreement to this limitation on nuclear testing by ourselves and our principal adversary will be seen by other parties as a positive and stabilizing step. It will be viewed as demonstrating leadership in the critical task of peacefully managing our relationship with the Soviet Union, while providing an example of self-restraint to all.

In addition, ratification of these treaties will build confidence and meet the reasonable expectations of our negotiating partners and others that arms control negotiations with the United States will result in concrete progress.

More importantly, we are hopeful that ratification of improved, verifiable agreements will open the path to more stable and predictable relations with the Soviets.

As the President said in his letter requesting your advice and consent, ratification of improved treaties that are effectively verifiable is a necessary first step to further progress.

If the Soviets agree to our proposals to make the treaties effectively verifiable, we will move into a new area of bilateral cooperation between our governments in the area of verification.

For the first time, both countries will allow direct onsite measurements of nuclear testing at nuclear testing sites. This will be a beneficial precedent for other arms control negotiations as well as a good step toward further limitations on nuclear testing.

Over the past two years, we have placed the highest priority in the area of nuclear testing limits on finding an effective means of verification of the 1974 TTBT and the 1976 PNET. We have proposed concrete means of building confidence by extending a unilateral and unconditional invitation to the Soviet Union to send experts to measure directly the yield of a nuclear test at our test site.

In March of 1986, the President urged the Soviet Union to join the United States in discussions on finding ways to reach agreement on the central verification improvements of the two treaties.

He invited Soviet scientists to come to our Nevada test site to examine our proposed verification system fully. He said the United States would be prepared to move forward on ratification of the TTBT and PNET if the Soviets would agree to effective verification.

The President has undertaken a series of additional concrete and practical steps. After several years of trying to engage the Soviets in expert level discussions, agreement was finally reached last summer.

A first meeting was held in July. A second meeting was held in September. And a third meeting took place in November.

On October 10, 1986, in Reykjavik, the President announced that as a first order of business for the 100th Congress he would request the advice and consent of the Senate to ratification of the TTBT and PNET but with an appropriate reservation to the treaties, which you have, ensuring they would not take effect until they are effectively verified.

Further, the President said that once our TTBT/PNET verification concerns have been satisfied and the treaties have been ratified, he would propose that the United States and the Soviet Union immediately engage in negotiations on ways to implement a step-by-step parallel program in association with a program to reduce and ultimately eliminate all nuclear weapons—of limiting and ultimately ending nuclear testing.

In our view, this is the most practical and serious approach to nuclear testing limitations. Yet, despite our efforts, the Soviets have not agreed to it. We remain hopeful they will join us.

We have left the door open to negotiation, and in fact, we have recently reiterated through diplomatic channels our proposals for the opening of negotiations with the Soviets in January.

The President's proposals in the nuclear testing and other arms control areas demonstrate our commitment to achieving the conditions necessary for possible additional limitations on nuclear testing in the process of a context of a process of nuclear arms reductions.

It is now up to the Soviet Union to make a similar commitment which they can demonstrate by negotiating in good faith when the President's proposal for central verification improvements to the existing treaties.

Some argue that these treaties do not go far enough; that the United States should seek a moratorium on testing instead. I want to make a few comments on that proposition.

First, as I have already said, nuclear testing is critical to nuclear deterrence, and deterrence is what has kept the peace in the Atlantic Treaty area for over four decades. That is a singular achievement.

Second, a moratorium, or a CTB, has no effect on the numbers or deployment of nuclear weapons. More important, it would not affect the threats to our security which forced us to arm in the first place.

Moreover, it is possible that focus on a comprehensive testing ban will divert attention and energy from the practical and achieveable steps of arms control represented by these treaties.

These treaties can enhance stability and security now, rather than in some distant future, and open the way to that future if the Soviets will agree to address it sincerely and meaningfully.

They constitute a significant step along an important path.

I wish also to point out the importance of maintaining adequate safeguards in conjunction with these treaties. We consider safeguards essential to ensuring the nation's ability to retain the technical means and knowledge necessary to support the nuclear deterrent and existing and future national security policies.

A description of these safeguards will be submitted for the record at the conclusion of our testimony.

The military authorities who will make presentations to this committee are prepared to give further details regarding safeguards.

In conclusion, we think there are good opportunities for progress in arms control, including nuclear testing. So far, however, the Soviets have been more interested in the grand gesture than in practical steps.

To summarize, we have made it absolutely clear that we require nuclear testing for our security and the security of our allies. We intend to continue with our testing program.

A nuclear testing moratorium is unacceptable. It diverts attention from the real issues. What is needed now is to enhance confidence in verification of the TTBT and PNET.

We've placed top priority on the achievement of a reasonable and effective system by which we can verify compliance with the TTBT and PNET.

The United States has made a series of concrete proposals to the USSR in this regard.

Four, we are prepared to open negotiations with the Soviets now. Once these treaties are effectively verifiable and have been ratified, we would proceed in accordance with the step-by-step process outlined by the President in Reykjavik last October.

We seek the Senate's advice and consent to these two treaties with an appropriate reservation. I ask for your continued support in our responsible approach to nuclear testing limitations.

Thank you.

The **CHAIRMAN**. Thank you very much, Mr. Holmes. I think before we get any questions, we would like to have all of the Administration's witnesses views before us.

Who will we have next?

Mr. **BARKER**. Senator Pell, I will follow.

The **CHAIRMAN**. Mr. Barker, please proceed.

STATEMENT OF HON. ROBERT B. BARKER, ASSISTANT TO THE SECRETARY OF DEFENSE (ATOMIC ENERGY)

Mr. **BARKER**. Mr. Chairman, I am pleased to have this opportunity to testify today on behalf of the Department of the Defense on the subject of Senate advice and consent to the Threshold Test Ban Treaty and Peaceful Nuclear Explosions Treaty.

I would ask permission to have my full statement included in the record, and just to proceed to summarize some of its key points.

The **Chairman**. I thank you very much indeed, because as you can see, there are quite a few witnesses, and we would like to get to questions.

So your full statement, and the full statement of all of the witnesses, will be inserted in the record as if read.

Mr. **Barker**. Thank you.

The Department of Defense fully supports the President's request for the Senate's advice and consent to the ratification of the TTBT and PNET, subject to the condition that the President shall not proceed with ratification until the United States and the Soviet Union have concluded additional protocols or other agreements which would be integral parts of the treaty and which would provide for effective verification of those treaties, including the right of each side to conduct accurate, direct, hydrodynamic yield measurements at the site of all nuclear detonations of the other side, which otherwise might appear to have yields in excess of 150 kilotons.

The Department of Defense also supports the idea of safeguards, and supports Senate consideration and support for such safeguards, similar to those which were a part of the Senate advice and consent in the 1963 Limited Test Ban Treaty.

We believe that safeguards can play a key role in protecting the national security interests of this country, and General Vesser will address this issue of safeguards in more detail later.

The Department of Defense, in looking at any treaty, clearly has a responsibility to consider the national security implications, the ability of the Department of Defense to continue to meet its responsibilities under the terms of any such treaty.

Clearly, we must understand the impact of the treaty provisions on our ability to meet defense requirements. We must also feel comfortable that the Soviet Union is as constrained as ourselves.

We, the United States, have been abiding by the provisions of the Threshold Test Ban Treaty, as you yourself pointed out, Senator, since 1976, over more than a decade.

During that time our defense programs have been impacted by the fact that we have adhered to the provisions of the Threshold Test Ban Treaty. We have had to deploy weapons systems without the ability to test those systems at full yield. We have received the assurance of the Department of Energy that they can proceed in such a manner with acceptable confidence, but clearly, it's patently at a reduced level over the level of confidence we would have were we able to test these devices underground at full yield.

So the U.S. defense program has been limited by our adherence to the Threshold Test Ban Treaty. It is critical to this country's interest that the Soviet Union is equally bound, and that we are confident that they are equally bound.

And that is the critical importance of the reservation that the President has included in his transmittal to the Senate, that these treaties not be ratified, that they not go into effect, until we are confident that we are in a position to determine Soviet compliance with their provisions.

We have learned ourselves that a single test can be sufficient to make the difference between having confidence and not having confidence in a stockpiled weapon.

Therefore, a single Soviet test in violation could, for them, make the total difference between their confidence that a weapon system will meet their objective for it, or, the other alternative, if they did not conduct such a test, might mean a total lack of confidence on their part in that particular weapon system.

So no one should come away with the feeling that there is no military significance to a single test in violation of the threshold. It would have significance for us. It certainly could have significance for the Soviet Union.

It continues to underline the importance of effective verification, not only for the Treshold Test Ban Treaty, but for all arms control agreements.

Our consideration of the Threshold Test Ban Treaty also gives us an opportunity to reexamine the important relationship between nuclear testing and the maintenance of nuclear deterrence.

The President's statement on October 10 at Reykjavik, which spelled out his program of the progressive consideration of further limitations on nuclear testing, which Ambassador Holmes outlined a moment ago, delineates a clear relationship between limitations on testing, and our ability to maintain a reliable deterrent under the conditions of those limitations. Therefore, as we consider further limitations on nuclear arms and as we reduce our dependence on nuclear testing to maintain that reliability, only then can we consider further limitations beyond the Threshold Test Ban Treaty, as far as nuclear testing is concerned.

Today, we have been told by the Department of Energy that we can meet all of our identified national security requirements with tests whose yields do not exceed 150 kilotons.

And we, indeed, support the Senate's advice and consent to the Threshold Test Ban Treaty for that reason, subject to achieving effective verification, and subject to the implementation of safeguards which will also enhance the ability to protect our national security.

Thank you, Senator. Thank you, Members.

[The statement of Mr. Barker may be found in the appendix.]

The CHAIRMAN. Thank you very much indeed, Mr. Barker.

General Vesser, please proceed.

STATEMENT OF LT. GEN. DALE A. VESSER, USA, DIRECTOR FOR STRATEGIC PLANS AND POLICY (J/5), ORGANIZATION OF THE JOINT CHIEFS OF STAFF, ACCOMPANIED BY BRIG. GEN. LEE DENSON, DEPUTY DIRECTOR, INTERNATIONAL NEGOTIATIONS (J/5), ORGANIZATION OF THE JOINT CHIEFS OF STAFF.

General VESSER. Thank you, Mr. Chairman, I have a statement for the record which outlines the military advice of the Chairman and Joint Chiefs of Staff in the matters under consideration by your committee today. I will summarize its contents for you.

The CHAIRMAN. Thank you. As I said earlier, your statement will be printed in full in the record.

General VESSER. The Joint Chiefs of Staff have provided military advice to the Secretary of Defense and to the President and to you for many years on nuclear treaty matters. Last year, Admiral Crowe testified regarding these issues.

The advice and recommendations of the Joint Chiefs of Staff have been consistent. They support the President's initiative in submitting the TTBT and the PNET Treaties to the Senate for advice and consent, providing that appropriate modifications are adopted which insure that our ability to deter attack on the United States and its allies is maintained and the United States is not placed at a military disadvantage as a result of ratification.

These modifications fall into two general categories. Improved verification measures must be incorporated into both treaties in some manner to assure compliance with the treaty provisions by the Soviet Union. Appropriate safeguards, including adequate verification, must be established to reduce associated military risks.

Let me elaborate on these two themes. The United States signed, but did not formally ratify, the TTBT in 1974 and the PNET in 1976. Nevertheless, we have complied with the terms of the TTBT, with a resulting disadvantage to our deterrent posture. As a result of compliance with the treaty, we have not explored advanced, high yield technologies to improve the effectiveness of our weapons. We have been unable to conduct full yield confidence tests on some existing weapons, and we have suffered a loss in qualified personnel who have the ability to conduct such tests if the need should arise.

While we were complying with the terms of the treaty, it appears likely that the Soviets have violated the 150 kiloton testing limit. But adequate verification of the terms of the treaty is not possible. This is why the President has made effective verification of both the TTBT and the PNET such a high priority. It is essential that ratification of the treaties not take place until the President is able to certify to you that the treaties are indeed verifiable.

As you consider ratification of these two treaties, I would like to reiterate the position adopted by the JCS regarding the need for adequate safeguards to assure our deterrent capability.

There must be provisions which permit testing consistent with treaty limitations. Testing enables us to insure that the weapons which provide our deterrent capability are safe and also enables us to achieve high confidence levels that all our weapon systems, both nuclear and conventional, will function effectively in a nuclear environment.

Testing enables us to maintain the credibility of our nuclear deterrent by assuring its effectiveness and reliability.

Finally, testing within the terms of the treaty ensures that we will not be surprised by Soviet actions which might render our deterrent ineffective and alter the strategic balance.

In conjunction with adequate testing provisions, we must maintain modern nuclear laboratory facilities. The United States must have the capability to resume nuclear testing which would be prohibited by these treaties if the actions of others make it necessary.

In addition to adequate verification programs previously mentioned, our nation must continue its emphasis on maintaining adequate intelligence gathering capabilities.

And finally, there must be provisions for independent U.S. Governmental review at periodic intervals to determine if renewal of the treaties is in the best interest of the national security.

With the adoption of suitable verification measures being contemplated and establishment of adequate safeguards, the Joint Chiefs of Staff support ratification of these treaties. I appreciate, sir, this opportunity to appear before you on behalf of the Chairman and the Joint Chiefs of Staff to discuss these important issues.

That concludes my opening remarks.

[The prepared statement of General Vesser may be found in the appendix.]

The CHAIRMAN. Thank you very much, General Vesser. Now we will hear from Mr. Foley.

STATEMENT OF ADM. SYLVESTER R. FOLEY, ASSISTANT SECRETARY FOR DEFENSE PROGRAMS, DEPARTMENT OF ENERGY

Admiral FOLEY. Mr. Chairman, I appreciate the time constraints under which the committee is operating today, and I would like to insert for the record the DOE policy paper, Nuclear Weapons Testing, and my remarks will be very brief and to the point.

The CHAIRMAN. Without objection, that will be in the record.

[The information referred to appears in the appendix.]

Admiral FOLEY. Thank you, sir. The Department of Energy strongly supports the President's proposal to ratify the Threshold Test Ban Treaty and the Peaceful Nuclear Explosion Treaty. These treaties, coupled with effective verification represent a positive step toward the much-desired goal of arms reduction between the Soviet Union and the United States.

Since these treaties were signed in 1974 and 1976, there has been considerable doubt concerning Soviet compliance with the 150 kiloton yield limit of the Threshold Treaty, and because of inadequate treaty verification capability, the Department of Energy, along with other U.S. Government agencies, has worked diligently to improve our national technical means of verification; specifically, teleseismic measurement.

There still remains with the presently employed seismic monitoring techniques a large measure of uncertainty in our ability to verify Soviet compliance.

Recognizing the critical need for a better verification method, the DOE laboratories have developed a direct, accurate, on-site hydrodynamic yield measurement technique called CORRTEX. This technique would significantly reduce the yield uncertainty available for exploitation by the Soviets. The on-site presence of U.S. and Soviet technicians would also reduce the possibilities of cheating and would increase the confidence of both sides in treaty compliance.

During the 11 years that these treaties have awaited ratification, the United States has complied fully with their provisions. The 150 kiloton limit has constrained our capability to address the full range of developing Soviet threats, as General Vesser has just mentioned. However, we have been able, within this constraint, to meet most of our military requirements.

For existing and new weapons systems, we have: one, improved their safety; two, increased their survivability; three, improved their command and control; and four, maintained their reliability.

Because of our ability to develop and test new warheads, we have accomplished the above without increasing the number or the total yield of the weapons in our arsenal during this period. The President has pledged to ratify these two treaties and then to proceed with a parallel program to reduce and ultimately eliminate both nuclear weapons and nuclear testing.

I wish to emphasize that further test restraints alone will not achieve these goals. Limitations on testing will not subtract a single weapon from either side's arsenal. What is needed is mutual, verifiable arms reduction. Ratification of these treaties with improved verification would be a significant confidence-building step towards this goal. The Department of Energy supports these efforts and encourages the Senate to assure that no further testing restraints are mandated prior to having appropriate arms reductions in place.

With regard to the TTBT and the Peaceful Nuclear Explosions Treaty, the Joint Chiefs of Staff have recommended that appropriate safeguards be adopted similar to those that accompany the Limited Test Ban Treaty of 1963 to reduce the military risk associated with these treaties.

These safeguards would include: continued underground testing consistent with treaty limitations; maintenance of modern nuclear laboratory facilities; maintenance of the basic capability to resume nuclear tests in the prohibited environments and yield ranges, should they become essential; a vigorous verification program and continued emphasis on intelligence activities; and, last, a period of review to determine if renewal of the treaties is in the U.S. national interest.

The Department of Energy endorses these safeguards and encourages the Senate to give them serious consideration as part of the ratification process.

The President's letter to you of January 13, 1987 contains a proposed reservation to the ratification process that would require that the Soviet Union conclude additional agreements with the United States that would provide for direct, accurate yield measurements taken at the site of all appropriate nuclear detonations.

The CORRTEX yield measurement technique with its supporting arrangements can provide the capability necessary to effectively verify these treaties and to alleviate the decade of United States Soviet mutual recriminations of violations based on inadequate verification methods. I encourage the Senate to adopt this reservation.

In conclusion, I recommend the ratification of these treaties with the reservation requiring effective verification that has been recommended by the President, and I endorse it as a positive step in the overall arms control process.

Thank you very much, Mr. Chairman, for the opportunity to present my remarks.

The **Chairman**. Thank you very much, Mr. Foley, and without objection we will insert into the record the communication from the President, including the text of his proposed reservation.

[The information referred to appears in the appendix.]

The CHAIRMAN. I think it also appropriate that we insert the article in Today's New York Times on Reagan Plan to Verify Nuclear Test Folded CORRTEX versus Seismic, and without objection that will be put in the record at this time.

[The information referred to appears in the appendix.]

The CHAIRMAN. Dr. McNally.

STATEMENT OF DR. JAMES H. McNALLY, DEPUTY ASSISTANT DIRECTOR, ARMS CONTROL AND DISARMMENT AGENCY

Dr. McNALLY. Thank you. Mr. Chairman, I note with interest and agreement that the press release you made announcing these hearings called for three basic results: First, was a clear commitment of both the administration and the Senate to effective verification; second, was to allow the President flexibility in further verification negotiations in Geneva, and third, was to affirm a mutual commitment to further contraints on testing and an ultimate end to all nuclear explosions. All three of these aims the Administration can agree with totally.

I think we have before us an opportunity to advance substantially the cause of arms control, if we do our job well. Conversely, I believe we can do great harm to the cause of arms control, and our national security, if we do our job poorly. If we are careful and patient, Congress and the Executive Branch working together can use these two treaties as powerful tools to create a major and needed improvement in arms control verification. Arms control as a whole will benefit.

Verification has always defined the outer limit of what one can achieve in the arms control business. Verification has always been a key part of the problem going back to the Baruch Plan in 1946. The direct measurement technique that we have heard about this morning can lead to major progress in negotiated verification provisions, if we can get agreement with the Soviets.

In 1983 and 1984 we made overtures to the Soviets to begin negotiations on direct measurement techniques for verfication. These were rebuffed. In 1986, we had three sessions, quite extensive sessions, with the Soviets on technical and other aspects of nuclear testing limitations. In 1987, we are optimistic that we can achieve further agreement and begin negotiation on the effective verification that we have outlined today.

Our experience in dealing with these treaties so far has been that they have engendered ambiguity and uncertainty. The New York Times article by Michael Gordon that you referred to mentions some of this ambiguity and uncertainty. I am not sure that any of us from the agencies represented here would find perfect agreement with all aspects of that article, but certainly there would be agreement on the fact that there is ambiguity and uncertainty with the verification provisions of the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty that were signed in 1974 and 1976.

Compliance has been a sticky issue. We admit that. The best way to accommodate that sticky issue in our minds is to move on progressively with a direct measurement technique. The direct measurement technique makes it possible to remove major systematic uncertainties, and in that way we can move out with a verification technique and procedure that will accomplish our goals.

The CORRTEX method is the only proven method that we have seen so far that can satisfy the effective verification goal. Indirect measurements and high explosive calibration tests will not accomplish our goal. The yield and geophysical differences attending such calibrations would not accomplish the reduction of uncertainty that we seek with the effective verification measures discussed with the Soviets. You will be hearing more about there discussions later this afternoon.

We know that the Soviets have developed similar direct measurement instrumentation for their own purposes. Pardon the pun, but the ground has already been partially broken by negotiation of the direct measurement technique that is incorporated in the Peaceful Nuclear Explosions Treaty. It is very similar to that which we propose for the Threshold Test Ban Treaty.

The effective verification that we seek will enable us to acquire information necessary to make a judgment in a timely manner on whether the Soviets are complying with agreed obligations. Removing compliance ambiguity can only lead to greater confidence in our negotiated agreements, thereby enhancing stability. The ability to unambiguously detect violations also serves as a deterrent to those who would seek to undermine our security by violating these treaty commitments.

Thank you very much.

[The prepared statement of Dr. McNally may be found in the appendix.]

The CHAIRMAN. Thank you very much indeed, Dr. McNally. I think we can start out with a ten-minute rule, and if more members come I will have made a mistake in judgment, but with the ten-minute rule we should be through about half past 12, and I would ask the timekeeper to start. I will take the first ten minutes.

I wonder if you could spell out even more specifically why the administration insists that the stronger verification provisions be negotiated before the treaties can enter into force. Presidents Ford and Nixon, as we know, considered them adequately verifiable as signed. There have been improvements in our techniques over the years since then, and we both are pretty well complying. I realize there is some question about the Soviets, but there has been a general abiding by the treaties without any apparent detrimental effect.

I was wondering if you could be a little bit more specific, any one of you, on this subject.

Mr. BARKER. Senator Pell, a great deal has changed, I think, since 1974 when the Threshold Test Ban Treaty was negotiated. The 1977 record is replete with administration witnesses who testified to their belief that the treaty was adequately verifiable. We have had more than a decade to learn that those views were, in fact, incorrect.

I would like to quote a statement made by Mr. Warnke, who at that time was the director of the Arms Control and Disarmament Agency. He said,

> It seems to us that verification is absolutely essential when you are dealing with nuclear explosives, test bans or limits, because otherwise you end up with a treaty

which is a source of friction and controversy rather than one which is an improvement in bilateral relations and one which is genuinely effective.[1]

The controversy that Dr. McNally referred to a moment ago about Soviet compliance is an issue that we have struggled with for the last three or four years. Certainly, at least, that is the period of time in which the President has formally informed the Congress of the United States that he believes that, despite ambiguities, the Soviet Union is in likely violation of their obligation.

As you are also well aware, that opinion has not been unanimously accepted. I cannot think of a more blatant example of a treaty which is a source of friction and controversy. As Mr. Warnke says, that is not adequate or effective verification.

So clearly we have a situation today in which we have had ten years to demonstrate that this treaty is not effectively verifiable. It is a source of controversy. It is a source of friction, and I think it would be a tragic mistake for the administration, for the Senate of the United States to give its advice and consent to a treaty which is not effectively verifiable, which would establish a standard, undermine a very, very important principle upon which all arms control should be based.

I could go into more technical detail about the reasons why the treaty is not effectively verified, but at the moment I would like to leave it with Mr. Warnke's definition of what constitutes effective, and that is a treaty in which there is not controversy about compliance.

Thank you.

The CHAIRMAN. I realize that this afternoon in closed session we will be able to get into some of these things in greater detail, but just from the viewpoint of all of us here in unclassified session, I was very struck with this article in the New York Times this morning.

As I understand it, the argument here is whether we use the CORRTEX system, which is a long wire going down, or the seismic system, which is the reverberations through the earth. Is that in essence what the argument is all about?

Mr. BARKER. I would like to defer possibly to Admiral Foley, but let me make one point. Today, the United States in its test program uses CORRTEX to help it understand the yield of U.S. tests. The United States certainly has available to it all kinds of seismic information about its own test program. I am sure the Department of Energy would not incur the cost of CORRTEX as part of the test program if it did not feel that it provided an accuracy substantially better than that which was available by seismic techniques.

Admiral FOLEY. That is absolutely accurate, sir. I agree completely with what Dr. Barker has said. In our test program for the Department of Energy, we use CORRTEX. We believe that we have verification with CORRTEX within a range of about 30 percent of uncertainty.

Now, this is a considerable closure from the range of uncertainty that we have with the seismic technology and with the very best of technical expertise in our laboratories. Examining the issue across the board, we have come to the realization that there is a much wider range of uncertainty with the seismic measurements than there is with CORRTEX. So we have used CORRTEX both down directly in the hole and in satellite hole, parallel to it and close by. The physics is the same in both, and there is no question in our minds about the fact that we are having much greater accuracy with CORRTEX. So we follow that, and this recommendation has been made to the Soviets. We have asked them to come and observe if they like, or if they have a technique that seems to be better, fine. We will be perfectly happy to examine that, too. We have not had a response from them, sir.

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[1] See p. — for Ambassador Warnke's response to Dr. Barker's citation of the above quotation.

The CHAIRMAN. Do we know whether they have that particular technique or not, or can you not say in this meeting?

Admiral FOLEY. I would ask Dr. Barker perhaps to take that question.

Mr. BARKER. Senator Pell, at the time of the negotiation of the Peaceful Nuclear Explosions Treaty, we discussed a technique at that time called SLIFER, S-L-I-F-E-R, which is based on the same physical principle of CORRTEX. CORRTEX is an improvement upon that technology. It is a more reliable technique.

The Soviets at that time, back in the 1974 to 1976 time frame, explained to us that they had a technique similar to the CORRTEX system that we were describing. In June of last year, Chairman Petrosyants, who is chairman of the State Committee on Utilization of Atomic Energy in the Soviet Union, who happens to be my counterpart in the nuclear test experts negotiations that have been going on in Geneva during 1986, made a speech to the Conference on Disarmament in Geneva. In that speech, he said that the Soviets had a system called MIS, M-I-S, which he said was as good as, if not more accurate than, the U.S. CORRTEX technique.

This afternoon in the executive session, I am prepared to discuss the substance of my discussions with the Soviets over the last six months and will be prepared to go into more detail at that time. Let me just summarize by saying the Soviets have claimed on numerous occasions that they have and understand the technology, and, in fact, have at times claimed that their capabilities are even better than ours.

The CHAIRMAN. Dr. McNally.

Dr. MCNALLY. Going back to your original question, I think it is quite clear that we can remove the bias and calibration concerns that are inherent in seismic methods with the direct measurement system. The system has been proven and demonstrated. The only thing that we would gain by going ahead with ratification at this point without the effective verification is a data exchange which, in itself, could not be verified. We would get some data, but we would not be able to check that it is accurate and correct.

So we have been living with the 150 kiloton threshold. The Soviets claim that they have been living with the 150 kiloton threshold. You have seen in the Gordon newspaper article, the amibiguity and uncertainty that has come about. If we went ahead with ratification right now, we would get a data exchange that was not verifiable, and I do not think we would be very far ahead.

The CHAIRMAN. I thank you. This afternoon, we can go into Mr. Gordon's article in greater depth.

The Soviet system, you say, is MIS?

Mr. **Barker**. MIS.

The **Chairman**. MIS, not MS. Good. I will desist at this time and would remind my colleagues that no, they do not have to fill up the ten minutes if they do not wish to. I would turn now to the Republican side. Senator Pressler.

Senator **Pressler**. Thank you very much. Many of my colleagues are very concerned that we are trusting the Russians too much with this treaty; that there is no on-site inspection; that the treaties were brought up on the eve of the Reykjavek meeting merely as a public relations gimmick; that we need additional reservations regarding verification; that the Soviets have violated the unratified SALT II, and they would violate these even more.

I might direct this question to General Vesser, whom I last saw when I was a Second Lieutenant in the Army in Vietnam, and I think you were a Captain then. That was about the highest level officer I ever talked to. [Laughter.]

I congratulate you on your great military career since.

In your professional, personal opinion, is there sufficient verification here?

General **Vesser**. I would say, in both my personal opinion and in that of the JCS, the CORRTEX technology will provide or can provide sufficient verification.

I do not personally believe that the treaty, without additional provisions, provides adequate verification.

Senator **Pressler**. Do you feel additional provisions are needed in the treaty?

General **Vesser**. Yes.

Senator **Pressler**. Even to the President's reservation?

General **Vesser**. Not beyond the President's reservation.

Senator **Pressler**. If we were to craft some amendments that would give us further assurances on verification, aside from your personal one, if you were advising this Committee, and we asked you what additional language could we add as an amendment in this Committee or on the Senate floor as an additional condition, what would you recommend?

General **Vesser**. I personally, and the JCS also, recommend adequate verification, which has already been discussed by witnesses more expert than I, in measurement. But in addition, strongly recommend appropriate safeguards.

Senator **Pressler**. There are some who say that the Joint Chiefs of Staff are endorsing these treaties because the White House has told them to, and the political system, the State Department, has told them to endorse them.

We have had historical examples, recently, of the Joint Chiefs of Staff in office and supporting a treaty, but then when they are retired, five years later, they say that really in their personal views they would have opposed this.

Do you think the Joint Chiefs of Staff, in their personal opinions, if they were out of office, would be enthused about this treaty?

General **Vesser**. I have a great deal of respect for the Chiefs, for whom I work. I do not anticipate any one of the current Chiefs opposing this treaty subsequently. But they do strongly recommend that we achieve adequate verification, and that we also consider appropriate safeguards.

Senator **Pressler**. We'll see what they say when they are retired.

In any event, let me just ask one more threshold question, and I can address this one to Mr. Holmes.

Why did the Administration bring this treaty up on the eve of the President's meeting? Was this a political move to lay a groundwork for arms talks?

I think when Ronald Reagan ran for President, if I recall correctly, and during the early stages of his Presidency, he was strongly opposed to this.

In fact, I think I recall once getting a letter from him before he was President stating that these two treaties were very dangerous, and now the Administration, just before Reykjavik, endorsed them, after opposing bringing them up.

Could you trace that history just a little bit, Mr. Holmes?

Ambassador **Holmes**. Senator, the technical discussions with the Soviets have been going on for two sessions, I think.

Mr. **Barker**. We started in July.

Ambassador **Holmes**. I believe that it seemed appropriate to the President, as he arrived at Reykjavik, to discuss primarily the nuclear and space talks issues, but in addition, knowing that the nuclear testing issue was one that would be on the agenda, that it would be an important stimulus to the Soviets to get on with the talks with us on nuclear testing, and to move from technical talks into negotiations on improving the verification of the TTBT and PNET according to our satisfaction.

I think he saw that as an important opportunity to put this issue squarely before Mr. Gorbachev as well as before the Congress.

Senator **Pressler**. Well, was there something that changed the Administration's position of opposition to these treaties, to support? If so, what was that event?

Ambassador **Holmes**. The Administration has since, I believe, 1983 supported the moving ahead with these treaties on condition that the verification system could be improved sufficient to provide effective verification.

Mr. **McNally**. But I think early in the President's term, he threw out the challenge: Is there a better way of verifying these treaties? And those were studied for a number of years.

As we go to the history that Ambassador Holmes has related.

Senator **Pressler**. Indeed, certain classified memoranda written by the U.S. intelligence community have recently been leaked, unfortunately, as the Chairman has pointed out, and I cannot raise these issues in open session. But we will have a closed session this afternoon, as I understand it.

But the key issue on the subject of those memos is the issue of verification. I guess that is the key issue that we will face in debate on this treaty and on the Senate floor.

President Reagan has proposed a reservation to the treaty ratification that would require an additional agreement, as you well know.

The question is a simple one: How rigorous must these measures be? So I would ask you, and perhaps I could get General Vesser to respond, specifically, do we need initial inspection of Soviet testing sites to confirm Soviet information and the geophysical characteristics of the sites?

Anybody may respond.

General **Vesser**. I would defer that to Admiral Foley.

Admiral **Foley**. You know, the more information you have sir, with regard to any particular site, the better off you are, if you know the characteristics of the site.

So quite clearly, knowing more of the geological characteristics would be useful to us. Is it absolutely essential that we have that before we would move forward? Not in my judgment, as long as we can utilize the CORRTEX, because I think this has been an evolutionary process, rather than any one single revolutionary event.

But we have greater confidence. We have done sufficient testing on this. We believe that it's certainly in the art of the possible. We do that now; not three years; not five years from now. You can go in and do CORRTEX testing now.

It enables us, then, to get on with improved verification, and we think that's desirable.

Senator **Pressler**. But we really can't get the geophysical characteristics of the sites from the CORRTEX system, can we?

Admiral **Foley**. I will take that one for the record, sir.

[The information referred to appears in the appendix.]

Mr. **Barker**. Senator Pressler, if I may, in the process of emplacing a CORRTEX instrument one must drill a hole approximately a foot in diameter down parallel to the hole in which the nuclear device is emplaced.

The core material that comes out of that hole would be available, in our minds, to those conducting the verification experiment.

And so that geophysical data would be available as part of any CORRTEX implementation process.

Senator **Pressler**. But you could probably misrepresent that somewhat. The Soviets seem obsessed with their opposition to on-site inspection, historically. They seem very uptight about any on-site inspection by human beings.

Why is that?

Mr. **Barker**. I am not sure I am going to climb into the Soviet mind. And I think maybe there is some evidence that their view has changed over the course of time.

Certainly, their willingness to accept CORRTEX would constitute a major shift.

Senator **Pressler**. Well, why wouldn't they accept on-site inspection by humans? We have said we will. Is it because the Soviets want to cheat on the treaties?

Mr. **Barker**. I think, Senator, that if we maintain the standard espoused by the President in March of this year of requiring 30 percent accuracy in yield determination for effective verification, the only way we can do that is via direct on-site yield measurements, by hydrodynamic techniques.

We know of no other way to do it. The Soviets will have to accept that process if these treaties are to be effectively verifiable.

Senator **Pressler**. Let me ask General Vesser, would the Joint Chiefs, if there were an amendment requiring on-site inspection, by human beings on each side, would the Joint Chiefs support it?

General **VESSER**. I would say that, yes, the Joint Chiefs would support that. But they don't think that it's essential to get the adequate verification.

We believe, as Admiral Foley, that the CORRTEX technology will provide that adequate verification.

Senator **PRESSLER**. The CORRTEX system is as good as on-site inspection by humans? I would have to disagree with that.

Mr. **BARKER**. Senator, I must interject, CORRTEX is on-site measurement. CORRTEX requires the measuring side to send in a team, which must be up to 15 people, to be on-site, to be there during the drilling of the hole.

Senator **PRESSLER**. But they are very limited in what they can do.

Mr. **BARKER**. That would all be spelled out in whatever agreements are subsequently negotiated with the Soviets that would define what effective verification is. CORRTEX can't be done without an on-site physical presence at the measurement site.

Senator **PRESSLER**. Well, there may be people drilling a hole. And when I talk about on-site inspection, I mean quite a different thing.

But I think my time has run out. I will pursue this later.

General **VESSER**. May I make one comment? I think from the security point of view, we must be concerned, as we look at the kind of on-site inspection you are addressing, sir, that it not be overly intrusive.

Because it is our intent to determine yield, not the specific things that either side is trying to determine from its test, that we would not want an on-site inspection which was overly intrusive, because it would not be, in my view, in our military interest.

The **CHAIRMAN**. Thank you very much.

The Senator from Maryland.

Senator **SARBANES**. Thank you, Mr. Chairman.

Secretary Holmes, I guess I will address this question to you.

How did the Administration formulate its position on this issue?

Ambassador **HOLMES**. I'm sorry?

Senator **SARBANES**. How has the Administration formulated its position on this issue? And particularly, what was the process by which this letter came to us from the President just today?

Ambassador **HOLMES**. Well, the letter was drawn up in the government, in the Department of State, with inputs from other agencies, and was also discussed with the members of the Senate staff.

Senator **SARBANES**. Well, is there an interagency task force that is working on this question?

Ambassador **HOLMES**. There is an interagency group that I chair.

Senator **SARBANES**. And who makes up that group? Is that on the public record?

Ambassador **HOLMES**. The members are the Department of State—basically the people at this table—the Department of Energy, the Department of Defense, the Joint Chiefs of Staff, ACDA, and also the intelligence community is represented, and our negotiator, Bob Barker.

Senator **SARBANES**. Are the individuals who are at this table and the agencies they represent, those that constitute the interagency group?

Ambassador **Holmes**. Yes, minus the intelligence representative, who I believe is appearing before you in closed session this afternoon.

Senator **Sarbanes**. Now, what do you understand the reservation that you are proposing to mean?

Ambassador **Holmes**. The reservation means that the President is seeking advice and consent on these treaties, but that they would not come into force until he certifies to the Congress that improved verification sufficient to achieve adequate verification has been negotiated in the form of protocols with the Soviets.

Senator **Sarbanes**. And what happens to that certification?

Ambassador **Holmes**. Well, the certification would be sent to the Senate, and upon being able to certify that the necessary improvements to the verification system have been negotiated with the Soviets, then the President would ratify the treaties following of course the advice and consent of the Senate.

Senator **Sarbanes**. The advice and consent of the Senate to what?

Ambassador **Holmes**. The advice and consent of the Senate to the treaties, and to the protocols improving the verification.

Senator **Sarbanes**. So in other words there are no treaties until the Senate ratifies the subsequent agreement; is that correct?

Ambassador **Holmes**. I'm sorry, would you repeat the question?

Senator **Sarbanes**. There are no treaties until the Senate ratifies a subsequent agreement beyond the ones that are now before us; is that correct?

Ambassador **Holmes**. Well, the treaties, they are treaties that exist right now, which we have been observing.

Senator **Sarbanes**. We have been observing them on what basis?

Ambassador **Holmes**. On a unilateral basis.

Senator **Sarbanes**. Then they aren't treaties.

Ambassador **Holmes**. Well, the text of the treaties have been before the Senate for some time. But what's different this time is that the President is seeking the advice and consent of the Senate to their ratification, subject to this reservation that I described.

Senator **Sarbanes**. Yes, but I am trying to find out what that means.

Ambassador **Holmes**. I'm not sure I understand your question.

Senator **Sarbanes**. As I understand it, your proposal is not to include in the treaties a reservation which, upon passage by the Senate and acceptance by the other parties to the treaty, would then constitute a binding treaty; is that correct?

Ambassador **Holmes**. My understanding is that the reservation would be included in the resolution drawn up by the Senate. But that is obviously for the Senate to decide.

Mr. **Barker**. Senator Sarbanes, I think we are disadvantaged by the fact that there are no lawyers here at the table.

The United States has been abiding by the Threshold——

Senator **Sarbanes**. Well, I don't think we need a lawyer for this issue. As I understand it, the reservation you are submitting is not a reservation drawn in such a way that its inclusion in the treaties in the course of their ratification would then put forth a document which, if accepted by the other side, would constitute a binding treaty.

Mr. **Barker**. That is correct. Because it is our objective, we believe that effective verification measures must be negotiated with the Soviet Union and cannot be dictated by the United States in the kind of reservation that I think you have just described.

And so what the President has done instead is, he has put forward language, and this is where a lawyer would be helpful.

Senator **Sarbanes**. What is you purpose, then, in seeking the approval of these treaties, if in fact it means nothing, since you are placing upon them the condition that they will only mean something if a subsequent agreement directed at verification is approved?

Ambassador **Holmes**. I think, Senator, what you have to do is to go back to the month of October, when the President sent his letter. Because at that time there was still a chance that we would have been able to conclude a negotiation with the Soviets on improving this verification system.

The President said that if we had negotiated the improvements to the verification system with the Soviets, then he would seek the advice and consent of the Senate.

He went on to say, however, that if by that time we had not concluded negotiations with the Soviets, he would still seek the advice and consent of the Senate, subject to this reservation.

Senator **Sarbanes**. And I am trying to find out what that latter position means. Why isn't it an empty position? I can understand the former position, which was that we are seeking to develop a verification protocol, and we will submit that as a condition to the treaty. When you pass the treaty, the other side will accept that protocol, and we will have a final treaty.

Now, what the President is saying, as I read it, is that this resolution of advice and consent to ratification is subject to the condition that the President shall not proceed with the ratification of these two treaties until he certifies that additional agreements have been reached on the verification question; and until such agreements have been submitted to the Senate, and the Senate has advised and consented to their ratification.

Ambassador **Holmes**. That's correct.

Senator **Sarbanes**. Now, why doesn't that make the action you are asking of us, in a sense, empty?

Mr. **Barker**. Senator, I think it is definitely not empty as far as the Soviets are concerned. I think for the Senate of the United States to take the position that ratification of the Threshold Test Ban Treaty should not proceed until effective verification measures are negotiated is a very significant message to the Soviet Union.

It indicates that the Senate of the United States and the Executive Branch are operating together. I think that such a message to the Soviet Union is bound to have a very positive impact upon their receptiveness to the negotiation process.

Senator **Sarbanes**. Well, couldn't we send the same message by not ratifying and simply waiting for the verification arrangements to be included?

Mr. **Barker**. That is an issue for the Senate to consider.

Senator **Cranston**. What was your response?

Mr. **Barker**. That is an issue for the Senate to consider.

Senator **Sarbanes**. In other words, you are coming up here and urging us to ratify these treaties, as I understand it, but attaching a condition to them that in effect makes their ratification meaningless, since they would only become applicable if we subsequently ratify another agreement relating to verification; is that correct?

Ambassador **Holmes**. As I understand it, I think it is the President that actually ratifies. We are seeking advice and consent of the Senate to ratification.

Senator **Sarbanes**. Accepting that modification, what is your response to the question?

Mr. **Barker**. Senator, the Congress, both the Senate and the House, have been encouraging the Administration for at least the four years that I have been in Washington to submit the Threshold Test Ban Treaty for Senate advice and consent, with a reservation, if the Administration has one.

The Administration has made clear all along that it does have concerns about ratification of these treaties in the absence of effective verification provisions.

So in one sense, the answer to your question is that the Administration is doing what it thought the Senate was asking of it—submitting the treaties, asking Senate advice and consent to what exists today, which we don't anticipate will change, and then asking the Senate to consider subsequent advice and consent to what would be negotiated, which will also clearly have an impact on whether this treaty in its totality is in the national security interest of the United States.

Senator **Sarbanes**. No, I think if you had not intended for this to be a meaningless exercise, that the provision you would have submitted with these treaties would be one—that dealt substantively with the verification question.

Then, in effect, you'd be saying, we have verification problems with these treaties. We now have this provision which we think addresses those questions. And therefore, we ask you to go ahead with a meaningful act and to approve the treaties with the verification provision.

What you are instead saying to us is, approve these treaties but place a condition upon them that they have absolutely no effect until we submit to you subsequently a further agreement which will also need to be approved before the treaties can take effect.

Ambassador **Holmes**. That is correct.

Senator **Sarbanes**. I am suggesting to you that that is really an empty act. There will be nothing of substance that will take effect until the subsequent agreement on which you are conditioning this is in effect reached, advised and consented to, and finally ratified by the President.

Isn't that correct?

Mr. **Barker**. That is correct, Senator Sarbanes.

Ambassador **Holmes**. That's correct. But I think it is important, the act of requesting advice and consent I think is an act of good faith on the part of the Administration vis-a-vis the Senate, and in addition, adds force, stimulus, to the Soviets to negotiate with us to agree to improve the verification procedures.

Senator **Sarbanes**. Well, I don't see that it adds stimulus, since the underlying question of approval of the treaties remains in any event.

Therefore, I am deeply puzzled as to why we are being called upon to do an empty act, which is what this amounts to, as I perceive it.

I see my time is up, Mr. Chairman.

The **Chairman**. Thank you.

The senior Senator from Washington.

Senator **Evans**. Thank you, Mr. Chairman.

Let me follow a little on the line of questioning of the Senate from Maryland, because I have essentially the same note written to myself during the course of the testimony that was given.

To put it more explicitly, would the Administration object to the Senate ratification of a treaty along with a reservation, that said, it will go into effect at such time as the Soviet agree to CORRTEX or an equivalent method of verification, without coming back for Senate advice and consent or further action?

Ambassador **Holmes**. Senator, it is really for the Senate to decide on these matters.

Senator **Evans**. Of course it is for the Senate to decide. But I'm saying, would the Administration agree with that position or object to that position?

Ambassador **Holmes**. You are suggesting that the second advice and consent would not be called for under that procedure?

Senator **Evans**. In essence. It seems to me that there is consistency of testimony here that CORRTEX or something equivalent to it is the requirement which you believe necessary to secure that the treaty could be verified.

Can't that explicitly be set forth in a reservation to the treaty at the time the treaty is adopted by the Senate? Then at such time as the Soviets agree to such language, the treaty goes into effect?

Why do we need anything more than that?

Mr. **Barker**. Senator Evans, I think that that approach is fraught with problems from the point of view of negotiation of an agreement with the Soviet Union.

I have been meeting with them now in three separate sessions in the latter half of 1986 in which the major thrust of our discussions has been improved verification of the Threshold Test Ban Treaty.

One thing I have learned is that one does not forward the negotiation process by dumping ultimata on the table. It seems to me that were we to try to spell out in total detail the kind of verification protocol that we might like, we are bound to face the Soviet perception that this is an ultimatum.

They are bound to want to negotiate some of the details; maybe some of those changes in detail would be ones that we could accept. Others might not be acceptable.

To spell out a reservation in sufficient detail that I think the Administration could, in good faith, ask the Senate to give its advice and consent, once and only once, is something that, in my opinion is inconsistent with a realistic impression of the negotiation process.

If we indeed are interested in furthering arms control and truly negotiating a threshold test ban, then I think the language in the current reservation, as the President has called it, has the flexibility necessary to permit negotiation of something that is acceptable, and something that will protect our national interest.

I am sure that during that process of negotiation with the Soviets, the Senate would be significantly interested in the course of those negotiations, and would remain interested in the details that were called for as far as verification was concerned.

Senator **Evans**. It sounds to me like all of that leads me to ask, why should we ratify the treaty now? We are not prepared.

Mr. **Barker**. I am not quite sure why we at the table have been beating around the bush on this issue. I think everyone in the room knows that when the Defense Authorization Bill went to conference this year, there were provisions in the House version of the bill which were very unacceptable to the Administration.

The Administration sat down with conferees on that bill and agreed to a total package that would describe Administration and U.S. Government policy toward nuclear test limitations from the Threshold Test Ban Treaty all the way through a comprehensive test ban.

Ambassador Holmes made reference to that total statement a moment ago. As part of that agreement, the language was developed which called upon the President—in which the President agreed to submit these treaties for advice and consent with a reservation as soon as the new Congress convened in January of this year.

The Administration is fulfilling its part of that commitment. We are doing it in the only way we know how, which continues to protect the national security interests of the United States, namely, by saying that we cannot ratify these treaties until we have negotiated provisions which allow them to be effectively verifiable.

So we have lived up to the commitment that was negotiated in October. We have done it in a way that we believe is consistent with protection of the United States national security interests.

It now is up to the Senate of the United States to see what action it will take in response to the President's fulfillment of his part of the commitment.

Senator **Evans**. Do you really believe, given the experience you have with Soviet negotiators, and the penchant of some of our negotiators, and their suspicion that at least during the course of the next two years, there's any hope of ever coming together on that provision?

Mr. **Barker**. I do, Senator. I would be happy to go into more detail in the executive session this afternoon on why I believe that, but I do believe it.

I especially believe it if the Senate of the United States does indeed endorse only giving its advice and consent to the TTBT after improved verification provisions have been negotiated.

Senator **Evans**. Let me touch on another element that I think was repeated in General Vesser's testimony and I think Mr. Barker's: the concern that we cannot conduct full yield tests because we have been unilaterally living up to the threshold test ban treaty.

Is that a real concern? We do lots of things in our society where we do not conduct full scale tests of what it is we are producing. Is that truly a concern or is that tossed in as just an extra argument?

Admiral FOLEY. That is truly a concern. There is no question about that, sir. You know, we are talking in terms of risk: Do I have confidence that the weapons will work, even though I can not test them at full yield? The answer is yes, I have a confidence zone but I will not give you a numerical number in here.

But do I have much increased confidence in the deterrence of the United States if I have fully tested that weapon? As I would any other system, be it an automobile or an aircraft or anything else, I test it to full capability and then you become confident that it is going to work.

To the best of our knowledge, with all the simulations, with all the component testing, we think it will work, but we do not know with full confidence that it will work. So in my judgment that is the risk that you take.

Senator EVANS. We have a lot of civilian nuclear power stations around the country with containment vessels; we do not test them with the ultimate accident.

Are you suggesting that we should be afraid, that we do not have full confidence in those containment vessels?

Admiral FOLEY. I will not address these, the civilian component of the nuclear industry, because, as you well know, sir, my responsibility is within that of the defense programs area of DOE. But we have confidence in them, yes.

But full confidence is a different issue. I am saying, if I had my druthers, if I had my choice, would I like to test to full yield? The answer is yes.

Senator EVANS. Well, we seldom have full confidence in anything. None of us have full confidence we are going to live out the day. But do you have sufficient confidence, given a 150 kiloton limit, in our weapons systems?

Admiral FOLEY. So far we have been able to live with that, sir, because of the kind of preliminary testing we did before the TTBT came into existence. Prior to that time, we had undertaken sufficient testing at high yields such that we have good ground work already in place to have confidence. That was ten years ago.

We are reaching the stage and moving on into a threat range now where that confidence in our ability to be able to produce the weapons to meet our needs is diminishing.

Senator EVANS. Perhaps we can get into this in further detail this afternoon.

As I remember testimony a year ago on seismic techniques indicated that there had been substantial improvements in the ability of seismic techniques to both detect low range tests and to distinguish between nuclear and natural events. Do any of you have a comment on those techniques as they relate to the so-called CORRTEX system?

Admiral FOLEY. There have been improvements, sir, but there remains sufficient ambiguity and sufficient uncertainty in the range of yield measurements by seismic measurement, that CORRTEX, by all our testing, appears to narrow that range of uncertainty and therefore is a more desirable methodology, and that is why the Department of Energy uses that methodology, because it is the best available now, sir.

Senator EVANS. Mr. Chairman, I wonder if I could follow up with just one other question that relates to this one. I know that my time has expired.

The CHAIRMAN. Certainly.

Senator EVANS. Thank you.

Using seismic and other technical means, you are talking about a two to one possibility, as I understand it, that a test could be twice as large as was suggested, and that CORRTEX will take it down to 30 percent.

So we are talking, on the upper range, for a test of 150 kilotons, that by seismic it might be as high as 300 kilotons, by CORRTEX it could be as high as 200 kilotons. I think I am essentially correct in those figures, 195 to 200.

Senator KERRY. Could you repeat that, Senator Evens?

Senator EVANS. If a test was listed as 150 kilotons, the outer limit might be as high as 300 kilotons under seismic means, and as high as 195 kilotons under CORRTEX.

How important is this treaty in the overall drive toward arms control, and is it sufficiently important that that differential in verification between 195 and 300—is that important? I mean, where is the balance?

Dr. MCNALLY. I think you have seen already, even in today's paper, the controversy that has come about because of the fact that the seismic methods inherently have a bias and a calibration that must be addressed somewhere. The CORRTEX system is a direct measurement.

You are measuring the yield a number of yards from the explosion, as opposed to hundreds or thousands of miles. You remove the systematic uncertainties and ambiguities that will lead to measurements that are always off by some unknown amount.

Senator EVANS. I understand all that, but you did not answer the question. Is it more important for us at this moment to go ahead and ratify the treaty, even if we only had seismic means of verification, as a move toward an arms control agreement?

Or is it more important for us to be sticky on making this step because we want to get from the potential of a two to one verification down to a 1.3 to one verification?

Mr. BARKER. Senator, it is very important that we be sticky. I cited Mr. Warnke's criteria for effective verification earlier, i.e., verification that gives rise to uncertainty, controversy, and friction is not effective verification, it's not good arms control.

We should not ratify any treaty which is as hard to verify as the Threshold Test Ban Treaty currently is because it generates uncertainty and friction that is harmful, I think, to the whole process. So rather than forwarding arms control, I would say ratification of the TTBT in its current form actually undermines the future of arms control.

Senator EVANS. Thank you.

The CHAIRMAN. The Senator from Massachusetts.

Senator SARBANES. Mr. Chairman, could I interject here?

Does not Mr. Warnke support these treaties as submitted to the Senate for ratification?

Mr. BARKER. I cannot speak for Mr. Warnke at the current time. What I was doing, Senator Sarbanes, was quoting from a statement made by Mr. Warnke in the Senate's 1977 hearings on these treaties.

Senator **Sarbanes**. Assuming he supports the treaties as submitted, it would really be less than straightforward with the Committee for you to be quoting Warnke for a contrary position, would it not?

Mr. **Barker**. Independent of his current position, Senator, I believe it is totally proper and fair for me to quote back to him and to quote back to the Committee the criteria that he established in 1977 for what he then felt constituted a requirement for effective verification.

Senator **Sarbanes**. But if he applies those criteria in this instance in such a way to support the treaties as submitted, it is not being straightforward on your part with the Committee to be quoting him in the context in which you are now doing, is that correct?

Mr. **Barker**. I would be happy to appear with him before this Committee at any time and debate him on that subject, Senator. I find it difficult to believe that he could, sticking with this principle that he espoused in 1977, find these treaties to be effectively verifiable today.

Maybe he has changed his standards in the meantime. I cannot speak to that.

The **Chairman**. The Senator from Massachusetts.

Senator **Kerry**. Thank you, Mr. Chairman.

Secretary Holmes, Mr. Barker, or anyone, when was the Soviet moratorium put into place?

Ambassador **Holmes**. When did it start?

Senator **Kerry**. Yes.

Ambassador **Holmes**. It started, I believe it was, August 6th, 1985.

Senator **Kerry**. And the last test prior to that moratorium by the Soviet Union was in July, is that correct?

Ambassador **Holmes**. I do not recall.

Mr. **Barker**. Yes, that is correct.

Senator **Kerry**. And since that moratorium was put into effect, have the Soviets tested?

Ambassador **Holmes**. To the best of our knowledge, they have not.

Senator **Kerry**. Has any country in the world alleged that they have tested?

Ambassador **Holmes**. I am not aware of it.

Senator **Kerry**. Do you believe they have tested?

Ambassador **Holmes**. I do not believe so.

Senator **Kerry**. Does anybody at this table believe they have tested?

Mr. **Barker**. Senator, under the current circumstances it is certainly possible for the Soviets to have tested without our detection because no verification mechanism is in place to verify a comprehensive test ban.

Senator **Kerry**. But it is true, is it not, that the current systems of verification that are in place, in which we have confidence, say that we can discern between an earthquake and nuclear explosion to an accuracy of approximately five to ten kilotons? Isn't that true?

Mr. **Barker**. I think it is inappropriate for us to get into those details in open session, Senator.

Senator **Kerry**. But this is a matter of public record. I have an article here from the Bulletin of Atomic Scientists by Hugh DeWitt, who works at the Lawrence Livermore Laboratory, which says exactly that. It is a matter of public record.

Mr. **Barker**. I cannot possibly vouch for the accuracy of Mr. DeWitt's statement. I think the intelligence community has been asked to testify this afternoon in executive session particularly for the purpose of addressing official U.S. government assessments of monitoring capability. I believe that is the proper forum for such a discussion.

Senator **Kerry**. You do not feel that you can comment on a matter of public record asserting a figure of five to ten kilotons?

Mr. **Barker**. No.

Senator **Kerry**. I mean, this has been stated in many, many public documents, has it not? Is it not a matter of public debate?

Mr. **Barker**. It is a matter of public debate, that is true.

Senator **Kerry**. And you do not feel that you can make a public opinion as to that?

Mr. **Barker**. As far as I am concerned, there are circumstances under which five to ten kiloton tests could be conducted which could not be competently identified by the United States with existing means as nuclear detonations.

Senator **Kerry**. But it is true, is it not, that you have to, in terms of military development of new weapons, reach a level of somewhere around 20 kilotons? Do you not?

Mr. **Barker**. Any nuclear test can be militarily significant if it is conducted in a way which addresses a specific problem which can be addressed at a low yield, or if it is used in a way which can maintain the expertise of nuclear weapon designers.

Senator **Kerry**. Well, let me ask you this. What percentage of our tests are for reliability? Is it about one or two percent?

Admiral **Foley**. There is no set percentage that we use for reliability, for safety, or for maintainability. One piggybacks on the other, particularly with the limited number of tests that we have now, Senator. We cram as much as we can in any single test: proof of physics and reliability as a stockpile weapon.

There is some percentage, that varies from year to year within a test program, that is utilized for reliability, for example. For example, it could be a third of the tests, it could be as many as a half. It could be a little bit less. It varies from year to year.

If I could get back to your previous question for a second, sir, I believe on Thursday you will have available to you the lab directors from both Los Alamos and Lawrence Livermore. I think it is more appropriate that they speak for the laboratory, rather than one of the individual scientists.

Senator **Kerry**. OK. With respect to the question—each of you has asserted the specter of constraints on the United States' ability to continue to develop adequately its deterrent and security posture. Have we been constrained in the last six years in our buildup of our military posture, our nuclear deterrent?

Since President Reagan came into office, have we been constrained?

General VESSER. I would say, with the reservations about full confidence that Admiral Foley expressed and the other items that I mentioned in my opening statement we have not been constrained, in terms of doing what is necessary in testing to field the forces in the current defense program.

In other words, we can test, and, even though there is some risk, that risk is acceptable in our judgment so long as we can test to the 150 kiloton limit.

Senator KERRY. And we have not exploded more than 150 kilotons, have we?

General VESSER. No, we have not.

Senator KERRY. So for the last six years we have not been constrained. We have not exploded more than 150 kilotons. Yet, in each of your testimonies, I believe, General Vesser, Admiral Foley, and one other, there is something that I find totally new in the debate and in the discussion about ratification.

And that is the suggestion on page 5 of Admiral Foley's testimony and the last page of General Vesser's testimony that there is the need for an additional provision, that the United States must be able to meet the Soviet threat while remaining in compliance with the constraints of the threshold test ban treaty, and that you cannot preclude the possibility that Soviet efforts to subvert that deterrent may create a situation that requires the United States to test above the 150 kiloton limit.

And in your testimony, Admiral Foley, you state maintenance of the basic capability to resume nuclear tests in the prohibited environments and yield ranges, should they become essential.

I sense in here the ground work for a breakout excuse, if you will, based on some perception that there are constraints here. And yet you said that there have been no constraints and we have not exploded.

I wonder if you would explain that for me.

Mr. BARKER. Senator Kerry, you are quite right that General Vesser, Admiral Foley, and I said there had been constraints.

Senator KERRY. Well, General Vesser said that there were not any constraints.

General VESSER. With qualifications.

Mr. BARKER. It depends very much upon how the word is interpreted. We will deploy Trident, we have deployed MX, we have several other systems in which we have not been able to test the warheads at full yield, but we have deployed them anyway.

We have developed methods and procedures as far as the nuclear warhead design is concerned. The lab directors on Thursday can address that in more detail. So we have been constrained.

We have had to develop an artificial set of rules which has limited us in ways we would not have been limited had we been able to test those systems at full yield. We could have pursued design alternatives that were not available because of the ground rules imposed upon the designers by the 150 kiloton limit.

So while we may have found ways around the 150 kiloton, we may have found ways to develop appropriate warheads under the 150 kiloton limit, it is totally inappropriate to say they have not been constrained. They were constrained and we will be constrained into the future.

In my testimony, I indicated the Department of Defense does indeed support the ratification of these treaties, subject to improved negotiation of effective verification.

Senator KERRY. But you are satisfied, as the President has said in his letter, as long as the Soviet Union is mutually constrained?

Mr. BARKER. Yes, mutual constraint is very important.

Senator KERRY. If there is that mutual constraint, why reserve the ability to break out?

Mr. BARKER. What do we do if the Soviets break out?

Senator KERRY. Is there not that ability anyway? If they breach the treaty, we have an automatic ability.

Mr. BARKER. If you look to the safeguards which the Senate of the United States took the initiative, I believe, in putting together in conjunction with its advice and consent to a limited test ban treaty, at that time the Senate recognized that capabilities do not automatically continue to exist after their apparent need has disappeared.

And what I think this particular safeguard addresses is the fact that, should the Soviets at some future point break out of a TTBT, if the Senate endorsed the safeguard, the Senate is putting itself on record as encouraging the laboratories to maintain the ability to resume high yield testing if the government should ask it to do so.

Senator KERRY. You said in your testimony, I think, Secretary Barker, that the Soviets maintain their high yield weapons through tests either at or above the 150 kiloton level, is that correct?

Mr. BARKER. At or above, or indeed, probably to make it more complete, possibly below.

Senator KERRY. Would it not therefore be in the United States' interests to try to set forth in this treaty a goal or our intent to try to abide by a lower threshold which remains within the satisfactory scope of the CORRTEX ability for verification, or even the external current ability, such as 20 kilotons, 10 kilotons?

Mr. BARKER. The directors of the nuclear weapons laboratories have testified before the Congress numerous times and have communicated to the Department of Defense that they are able and will be able to meet identified military requirements if they can test at 150 kilotons. The Defense Department certainly has received no assurances that they can continue to meet military requirements if they are restricted to a level below 150 kilotons.

Senator KERRY. Mr. Chairman, I see that my time is up. May I just ask your indulgence for one quick question?

The CHAIRMAN. Yes.

Senator KERRY. Each of you I think has said that not one nuclear weapon will be limited by a test ban, comprehensive or otherwise; is that correct? I heard you say that, Admiral Foley. I believe it was in your testimony.

Is there a disagreement with that?

Mr. BARKER. By that, Senator, you mean that no weapon will be destroyed because of it?

Senator KERRY. You will agree that no new nuclear weapon can be created if there is no testing, would you not?

Mr. BARKER. If there is no testing?

Senator KERRY. Could not be deployed?

Mr. BARKER. One could build innumerable numbers.

Senator KERRY. But you would not deploy a system and have confidence in it if you had not tested it?

Mr. BARKER. A new weapon?

Senator KERRY. Is that correct?

Admiral FOLEY. Let me take that, if I may, sir. I would not, that is correct, I would not deploy. That does not mean that others could not.

For example, I think Chernobyl is a perfect example that the Soviets lack a safety conscience. There is no question in my mind about that. First and foremost, we have one. Safety dominates all of our considerations. We would not develop and deploy a nuclear weapon without the ability to test.

That does not mean that others would not.

Senator KERRY. A new nuclear weapon?

Admiral FOLEY. Yes, sir, one of new design and complexity, not joint a modification of an existing weapon.

Senator KERRY. OK. Thank you very much.

Thank you very much, Mr. Chairman.

The CHAIRMAN. The junior Senator from Washington.

Senator ADAMS. Thank you, Mr. Chairman.

Gentlemen, I understand that all of you indicated that we have been disadvantaged by the fact that we have observed a 150 kiloton limit, is that correct?

[General Vesser nods affirmatively.]

Admiral FOLEY. Yes.

[Mr. Barker nods affirmatively.]

Senator ADAMS. And I think you also have stated in your testimony with some agreement that verification techniques have been improving since these treaties were originally signed, is that correct?

Ambassador HOLMES. Yes, Senator.

[General Vesser nods affirmatively.]

Senator ADAMS. Now, as I understand it, these treaties were sent to the Senate to carry out basically a political or call it symbolic—and I use "political" with a small "p"—promise by the Administration that they would be sent for ratification to the Senate as a first order of business, is that not correct?

Mr. BARKER. Senator, speaking personally, I agree. But I also point out that as far as I am concerned there is a very substantial benefit to the Senate giving its advice and consent subject to the kind of reservation which is proposed, which the President has proposed.

Senator ADAMS. I understand that. That is your position. I was not asking that.

It is a symbolic and political act to send these treaties up and ask that we ratify them. You have stated to the Senator from Maryland that this is an empty gesture until we at least ratify a second time. So could we not get really a backlash or bad effect if we ratify a treaty that in effect does nothing until we ratify a second one?

Mr. Holmes, I would like to have you comment on that.

Ambassador HOLMES. Senator, first of all, I do not believe that any Administration witness said it would be an empty gesture.

Senator **Adams**. Well then, I will rephrase that. This treaty would not have any effect until a second treaty or protocol was submitted to the Senate for ratification; is that correct?

Ambassador **Holmes**. That is essentially correct, that it would not go into effect until the President certified.

Senator **Adams**. And sent it back to the Senate and there was a second one?

Ambassador **Holmes**. That's right.

Senator **Adams**. So you do not agree with the fact that it is an empty gesture, but you agree that nothing would happen out of it?

Ambassador **Holmes**. It would not go into effect until that process took place, that is correct.

Senator **Adams**. You have indicated that verification techniques will continue to improve, and the senior Senator from Washington indicated that what we are really arguing about, according to the agreed testimony of all of you, is someplace between a two to one and a 1.3 to one.

Why are you asking us to act on a treaty that would not go into effect, as opposed to what the senior Senator from Washington suggested, at least have a reservation spelled out. If it is true that verification techniques are going to continue to improve we would never arrive at the second treaty, would we, Mr. Holmes?

Ambassador **Holmes**. If we can get the Soviets to agree to accept the hydrodynamic yield system which we now have, we believe that we would be in position to certify that we have effective verification.

Senator **Adams**. If we are going to do that, then, Mr. Holmes, why not place that as a reservation in the treaty, so that we at least have completed the ratification process, we have symbolically or politically carried out what the President said at the Iceland meetings, what you are asking us to do, and stop arguing about the percentage of verification, because all the testimony here has indicated there was an argument about percentage of verification.

Now, if we get into an argument with the Soviets as to the verification percentage or system—and you have already said CORRTEX was acceptable to the Administration—then we never arrive at the second treaty, because you are still arguing about the new and improving techniques, are we not?

Mr. **Barker**. Senator, I believe that the situation you are describing is one that, at least for me is hard to visualize happening. Senator Evans earlier talked about the fact that seismic technology has improved over the last decade in its ability to detect and identify seismic events.

That is true. But as far as I am concerned, the technology, seismic technology, has not improved much in its ability to estimate yields. And in this situation what we are talking about is the ability to evaluate yields, to measure yields by some scientific technique.

Those experts in 1974 who said they could estimate yields by seismic techniques——

Senator **Adams**. Wait a minute. I understand that you have made the estimates there and we have had the testimony that the techniques have improved, and you have suggested a system that is acceptable and it improves verification by so many percentage points.

And I assume that at times in the future it will improve again. All I am asking is, you have got a system that you say is acceptable. You want to move forward with the Soviets. Two Administrations, the Nixon Administration and the Ford Administration, agreed to the verification percentage at that time, which you do not find acceptable now.

You have got one now. Why do we not proceed with that, and if the Soviets do not accept it then you have your verification argument? But if we leave this hanging open and have not offered them anything, we have not moved this forward.

And the people of my State, the State of Washington, do not have a theoretical interest in this. We are involved in the production of plutonium. We are deeply involved in all the problems involved with that, and we would like to see some limits.

And it seems to me that 150 kilotons, when we are arguing about a percentage of whether we can tell whether it is 300 or 195, that we should be moving toward a treaty and, perhaps, require them to say, "we will not allow you to use your system," and not simply leave it hanging.

And I want to know whether the Administration is going to offer support or not if we come forward with a reservation that says verification shall include what you all have said was acceptable and not have to go to a second treaty.

I just want to know whether, if we pass this treaty with a reservation, that we are going to have support from the Administration so we can move forward with these treaties which are not a dire limitation according to testimony of everybody here, but rather a minimal political step forward.

Mr. BARKER. Senator, I think we would indeed be interested in working with your staff to see if we could create such language.

Again, in answer to Senator Evans' earlier question, at some point you get down to a level of detail that is probably inappropriate.

Senator ADAMS. I know, and I am not going to discuss the details. We can get into that this afternoon in closed session; but what I am talking about is the basic principle. We have here your unified testimony on a verification system. You have a statement that you want to carry out a ratification, and I do not want to go through an empty gesture here, or whatever you want to call it, to come up with a second one.

We are either going to go with a treaty or not, and I want to know whether the administration, if we accept the sort of additional verification the administration has suggested, is going to support us when we come out and say, "alright, we ratify these two treaties with a system that you have stated." That is all I want to know.

Mr. BARKER. It sounds to me like there is a basis for agreement, Senator, but I think we need to look at the language together to see if we are talking about the same thing. We are prepared to go forward with CORRTEX and use CORRTEX, and if the Soviets agree to CORRTEX——

Senator ADAMS. We will go forward if we have that kind of reservation so that we end up with a treaty?

Mr. **Barker**. Yes.

Senator **Adams**. Not a treaty that we are going to have a second behind it, but a treaty now.

[Mr. Barker nods affirmatively.]

Senator **Adams**. Thank you. Thank you, Mr. Chairman.

The **Chairman**. Thank you. I would interpolate here that we have had these meetings going on for the last few days of this group and its subordinates seeking to do exactly that. What I gather has just been suggested is that group stay in negotiation with each other and work on language along the lines that the Senator from Maryland has pointed out and both Senators from Washington have pointed out is necessary.

It might even be a good idea if the people at the meeting were the principals and not the subordinates, but I would leave that to you, because obviously concessions have to be made to reach an agreement on both sides, on all sides.

Ambassador **Holmes**. We would be very pleased, Senator, to continue the discussions on the reservation.

The **Chairman**. At my request, our own staffs will participate, and as soon as we have a ranking minority member we will be able to talk even more specifically.

We still have a little time left. I will forego my questions, and I would just suggest that each member limit himself to five minutes, maybe less.

Senator Pressler.

Senator **Pressler**. Thank you, Mr. Chairman. I am becoming more doubtful about this CORRTEX system as I hear more about it. Let us get back to the basics.

The administration decided to add a reservation, and I do not accept that this is on-site inspection because you send 15 technicians over to drill a hole, whose job is a technical one, but it has been proposed that there be an international team of experts who would verify. They would go to each country, and if there are suspected violations they would go to the site and see and get firsthand information.

Why does the administration not propose such a reservation to this treaty?

Ambassador **Holmes**. Senator, I think, given the fact that this is a bilateral negotiation between us and the Soviet Union, we think it is very important that it be a government-to-government agreement and that the verification procedures be conducted by officials of our nations.

Senator **Pressler**. OK. Forget about the other country. Let us say teams. Let us say there is a suspected violation, and we send a team of five people to look at it on each side. What would be wrong with that?

Mr. **Barker**. Senator Pressler, I think there has been no physical mechanism identified which would allow you to determine whether a test in excess of 150 kilotons had occurred. In other words, if a suspicious event occurred that appeared to us to be above 150 kilotons, there is no scientific measurement that could be made after the test was completed that would enable us to determine whether a violation had occurred or not.

That is why CORRTEX has to be in——

Senator **Pressler**. There would be some scientific way. If you sent a team there that could measure it, I think.

Mr. **Barker**. Not after the fact.

Senator **Pressler**. Are the people there just technicians, or are there people there who could make judgments?

Mr. **Barker**. I think we tend to view them as technicians who can make judgments, yes.

Senator **Pressler**. I would be very concerned about who was there. I think you know what I am talking about.

Let me ask General Vesser. What exactly are the specific returns to the United States in the military field on treaty ratification? We spent a lot of money on national defense out here. What are we going to get of this from a military point of view?

General **Vesser**. I think that is a very good question, Senator. We think what we are going to get out of it, with effective verification, is the confidence that the Soviets are equally and mutually restrained as we have been by observing the 150 kiloton test limit. Specifically, if they exceed that limit regularly, there is a possibility that they can move ahead in high yield weapons design, a matter clearly of some concern given their greater throw weight. So we see that such a treaty, with this kind of a threshold and with adequate verification, will limit them and they will not get a military advantage.

Senator **Pressler**. So as a professional military man, you are saying that there are military returns to the United States in this treaty?

General **Vesser**. Yes, because we are currently observing the treaty scrupulously ourselves but do not, I believe, have confidence that the other side is doing so.

Senator **Pressler**. I have been given a note that my time is up. Mr. Chairman, I ask unanimous consent to ask the rest of my questions on the record.

The **Chairman**. Without objection.

The Senator from Maryland is recognized.

Senator **Sarbanes**. Who is the author of the proposed reservation that has been submitted to us in the letter from the President?

Ambassador **Holmes**. There are a number of authors, partly administration officials and partly members of the Senate Foreign Relations Committee staff.

Senator **Sarbanes**. Leaving the staff out of it, which administration officials are the authors of this reservation?

Ambassador **Holmes**. The Department of State and Defense, ACDA.

Senator **Sarbanes**. Does that mean you when you say Department of State?

Ambassador **Holmes**. I did not, myself, write it, but people working for me did actually draft. In fact, my senior deputy has been in charge of this effort, John Hawes.

Senator **Sarbanes**. Now, first of all, this reservation is unlike any reservation I have ever seen, and I would appreciate the Department finding me a comparable reservation. A reservation is usually to a treaty and is part of that ratification arrangement.

This reservation is, in a sense, to create the conditions that yet another treaty must be passed before this one takes effect; is that correct?

Ambassador HOLMES. That is correct.

Senator SARBANES. If there is a comparable instance of such a reservation, I would like to know about it. Perhaps you can check and let me know that.

Ambassador HOLMES. We will check and see if we can find an example.

[The information referred to appears in the appendix.]

Senator SARBANES. Assuming it were done this way, would you expect there to be continued adherence to the limitations of the test ban treaty in the interim period, while efforts were being made to arrive at this agreement?

Ambassador HOLMES. We will certainly continue, the United States will continue to observe the limitations of the treaty as we have from the beginning, for over 10 years.

Senator SARBANES. So you would expect to go on observing the limits?

Ambassador HOLMES. We would.

Senator SARBANES. Now, suppose this were done and then it was decided that we wanted to pass the treaties as submitted; a judgment was reached that the treaties, as submitted, could adequately protect our interests.

Would it be possible then to do so?

Ambassador HOLMES. The administration would not wish to ratify the treaty in its present form.

Senator SARBANES. No, that is the substance of the position. I want to know if these treaties are ratified subject to this condition, and subsequently a determination were made to ratify the treaties as submitted, would that be possible?

Ambassador HOLMES. That is the kind of subject that we would discuss with you.

Senator SARBANES. I think the answer to that is obviously "no". If the treaties are ratified with this condition, I do not see how we could then get the treaties back and ratify them as submitted.

Let me put the question more pointedly. Would not this approach in effect preclude the possibility of subsequently ratifying the treaties as submitted?

Ambassador HOLMES. Subject to the reservation, do you mean, that the President certify that the verification——

Senator SARBANES. Adoption of this reservation as you have submitted it and the passage of the treaties subject to that reservation would then preclude any possibility of ratifying the treaties as submitted; is that not correct?

Ambassador HOLMES. I want to just understand your question. You are suggesting that this would be without a negotiation of the protocols with the Soviets including the hydrodynamic yield system?

Senator SARBANES. That is right.

Ambassador HOLMES. No. We would not wish it to be ratified, and the President would not ratify minus that improvement in the verification system.

Senator SARBANES. I understand that, but what you have done here is you have precluded that possibility, have you not?

Mr. BARKER. I think we hope so, Senator.

Ambassador HOLMES. I think it is precluded.

Senator SARBANES. It is a way of taking these treaties off the calendar as submitted. That is one of the consequences of this approach, is it not?

Ambassador HOLMES. That is really for the Senate to determine. That is certainly not our intent.

Senator SARBANES. Look, I am not trying to play a game. Let us find out exactly what it does.

Is it not the case that approval of these treaties with your reservation would preclude, then, any possibility of approving the treaties as submitted if that is the position someone wanted to take?

Ambassador HOLMES. Yes.

Senator SARBANES. Is that not the case?

Ambassador HOLMES. Yes, that is the case.

Senator SARBANES. Thank you.

Ambassador HOLMES. I was just trying to understand your question.

Senator SARBANES. Let me ask one other question of General Vesser. I read your statement, a statement of the Joint Chiefs, carefully, and in the second paragraph, the first substantive paragraph, you state, and I quote, "The Chairman and the Joint Chiefs support in principle ratification of these treaties. That support, however, is with the understanding that the improved verification measures being contemplated are incorporated into the treaties as protocols or other appropriate codicils prior to ratification and that appropriate safeguards are adopted to reduce, insofar as possible, the military risks associated with these treaties." Those safeguards deal with a number of other matters which you would like to be assured about that are in a sense outside of the treaty, relate to the maintenance of certain capacities and so forth and so on.

I interpret that paragraph to mean that the Chairman and the Joint Chiefs were proceeding on the premise that the treaties would encompass within them the verification provisions and that, in a sense, they assumed a somewhat different approach than what is contained in the reservation that has been submitted to the committee.

Is that correct?

General VESSER. I would respond that we would see that it is possible for them to be submitted as an additional agreement for ratification but certainly——

Senator SARBANES. But that was not the premise you were proceeding on when you wrote that paragraph, I assume?

General VESSER. That is correct, and that correctly states the position of the Chairman and the Joint Chiefs.

Senator SARBANES. Gentlemen, let me simply say to you I interpreted the President's letter of October 10 as, in effect, saying that they would negotiate an arrangement with the Soviet Union on verification which would be encompassed within this treaty or, that failing that, a substantive provision on verification would be contained in this treaty which would represent our judgment as to what constituted a reasonable position on the verification question.

Instead, they are playing a game with this reservation that makes action on the treaties empty, since it would require subsequent action in order to have any meaning, and would have the additional impact of wiping out the option of approving the treaties as submitted.

Now, you may want that to happen, but others may not want that to happen. But certainly one consequence of approving the treaties with the reservation as you have written it would be to take the treaties off the calendar and with that the possibility of ratifying them as is.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you. The senior Senator from Washington.

Senator EVANS. Mr. Chairman, first I hope we can clear the air from some of the line of questioning of Senator Pressler.

Is it accurate to say that the best experts in the world standing there watching a nuclear test cannot scratch their head and say, well, it looks like it is about 150 kilotons to me? The verification has to come throughout whatever techniques, seismic tests, CORRTEX or whatever devices we have. It is beyond human capability to accurately measure a nuclear test just by watching. Is that not accurate?

Ambassador HOLMES. Yes.

Dr. MCNALLY. Yes, sir.

Senator EVANS. This question is not directed to the panel so much as to my colleagues. As far as removing an original treaty, I wonder if we had ratified a treaty with certain reservations, would it still not be possible for us to come back later and remove those reservations if we chose to do so?

Senator SARBANES. Not the way this is written. The way this is written, this would then go to the President for the purposes of——

Senator EVANS. That is certification back to Congress?

Senator SARBANES [continuing]. Of putting it into effect, and I think, therefore, that the ability to ratify these treaties as submitted, if one chose to do that—one may choose not to do that—would be lost. The administration is opposed to doing that, but as a legal matter, I think that option would be foreclosed, and that is one of the consequences of this resolution as submitted to us.

Dr. MCNALLY. I think the Soviets would find it very interesting, if the Administration and the Senate were together on the advice and consent and ratification procedures.

Dr. Barker has made the point a number of times that the Soviets are watching what we are doing and that a position taken together by the Administration and the Senate on the need for effective verification is one that should be underscored to the Soviets.

Senator SARBANES. How would it differ from turning the treaties down and saying to negotiate another treaty with better verification? Is that not in effect what it amounts to?

Dr. MCNALLY. That is splitting a hair that I would not want to split. There was something on the order of a year and a half of negotiations with the Soviets before agreeing to the Peaceful Nuclear Explosions Treaty. In adapting the PNET direct measurement method, a direct measurement technique very similar to the one that we are now talking about, we could avoid starting over from scratch. We are hoping to gain effective verification by modification of the existing treaties.

Senator EVANS. I think all three of us, the Senator from Maryland and my colleague from Washington and I, have been asking essentially the same question, and I detect we have been getting somewhat different answers, depending on who asked or how the question was asked.

Let me get back to it and see if we can get, quite explicitly, just where we are. First, let me precede that by suggesting that the answer to my question, I think, was if we put a detailed and explicit proviso in this treaty, then the Soviets would want to change it, and we would be into negotiation.

Would it not be just as likely that the Soviets would be wary as the devil of signing up to a treaty that had already been agreed to by the Senate? They would subject it to long negotiations. They might agree to negotiations and take the chance that they would be embarrassed after those negotiations were concluded because the Senate would not approve. What then?

In other words, we would get two bites at the apple. I would think they would be wary as the devil of engaging in and concluding agreements with the administration, knowing that they would have to go back for a second advise and consent, depending on whatever political circumstances happened to exist at the time.

It seems to me, at least, that that is as big a danger as the danger you pose of putting explicitly in a treaty what we want and laying it out in front of the Soviets and having them reject it. Is that not as big a possibility?

Dr. MCNALLY. I think, again, there is a little difference of view. One might hope that the Administration and the Senate could get together on some, shall we call it, course structure or general key elements of what we might need in a treaty, but the details of those elements and what gets hung on the elements in order to make the last "i" dotted and "t" crossed is an area that requires quite an elaborate series of negotiations with the Soviets.

Now, building on the year and a half that we have already had in 1975 and 1976, it should not be too difficult a job, but we do need the flexibility. We cannot be presumptuous enough to sit there and say that the agreement we would devise ourselves would be acceptable to the Soviets. Perhaps they have some genuine problems with part of the fine structure that one would put on.

Senator EVANS. To what degree do treaties and protocols as advised and consented to by the Senate encompass every dotted "i" and crossed "t", and to what degree do you in any treaty and the carrying out of that treaty add to it the methodology and the details in terms of how the treaty is carried out?

Dr. MCNALLY. Let me twist that around just slightly differently. Any treaty that is presented to the Senate is presented to the Senate in a relatively brief form. There are reams of negotiating history that have gone on behind the treaty in the negotiating process.

Senator EVANS. I understand all that.

Dr. MCNALLY. So those details can affect many of the things that are then regarded later as being substantial in the compliance process.

Mr. **Barker**. Senator Evans, I would like to look to the Peaceful Nuclear Explosions Treaty as a model at least in terms of structure, because it does spell out in a great amount of detail the verification measures that are associated with that treaty. Therefore, at the time when the Senate would give its advice and consent, it would have the totality of the verification measures before it and would have a mechanism for assuring itself that any agreement is in the national security interest of the United States.

I was a little puzzled, in fact even disturbed, by your initial comments to Dr. McNally. I am not sure about your experience with the Soviets, but in my own I have been harangued more than once about this complicated process in the United States whereby once a president signs a piece of paper it is not automatically reduced to law, and why do we have this silly advice and consent process.

I think that that is a very good and sound process that does, indeed, go a long way to insuring that the best interests of the United States are protected. I have been proud of it. In fact, I have had the opportunity to tell the Soviets that more than once.

So I think it is very important. It is something of which we should be proud. Yes, it is complicated. Yes, it means that there is one more step that has to be taken, but I think it is one that has stood us in good stead, and I would be very happy to look in the eye of any Soviet counterpart and say yes after I am done and done the best job I can, and even if I have convinced the President of the United States to sign this piece of paper, you must indeed go through one more step, and that is get Senate advice and consent that this piece of paper is in the best interest of the United States.

Senator **Evans**. You do not have to give me that lecture.

Mr. **Barker**. Sorry. [Laughter.]

Senator **Evans**. I am on our side. [Laughter.]

But if I could pursue that, frankly, we want to very carefully give advice and consent to as complete a document as we can. I am a little concerned that we may give advice and consent not knowing what that second agreement might be, and when you come back here for the second ratification, some of us may be sorry we ratified in the first place.

I think it would be much better if we can contrive to do so. You said in the Peaceful Nuclear Explosions Treaty that we have a treaty which is a short treaty and a detailed protocol. It seems to me that what we ought to have here is, again, a short treaty and either a revised protocol, which probably cannot be achieved, or maybe it can, or a protocol together with an explicit reservation.

I thought I heard you say in response to the questions from my colleague from Washington that maybe you could work in that direction and get to that point where we could do this on a one shot basis.

Mr. **Barker**. I am sorry to the extent that I may have contributed to the conclusion. I think Dr. McNally did a very good job of summarizing what my intent was and why I thought I was being consistent both in my response to you, Senator Evans, and in my response to Senator Adams.

I think to go into too fine a detail is doomed to failure as far as the negotiation process is concerned, as far as moving this treaty forward. I think that laying out a course structure may be possible in sufficient detail to satisfy both Senator Adams and yourself and still leave us room to negotiate the details; but until we actually sit down and try that process, I am not sure we can succeed.

Senator **Evans**. Those details you are talking about are details you still think need to be ratified as part of the treaty?

Mr. **Barker**. I think they have a direct bearing on whether the treaty is in the security interest of the United States, yes.

Senator **Evans**. Thank you, Mr. Chairman. I would ask unanimous consent that Senator Lugar has a list of questions he wanted to make sure were asked for the record.

The **Chairman**. Not only that, but Senator Helms has some questions, so I would suggest the record be kept open for any senators who have questions that they would like to submit.

Senator **Sarbanes** wants to interpolate for a moment here. Please excuse us, Senator Adams.

Senator **Sarbanes**. Mr. Barker, I took issue with you earlier, quoting Ambassador Warnke, and said I thought it was being less than straightforward with the committee, to use his quote, when I understood the substance of his position to be for the ratification of these treaties as submitted.

We have been in touch with Ambassador Warnke about the quotation that you used, and he comments as follows: [1]

> The TTB and PNE treaties were negotiated in 1974 and 1976, respectively, by Republican administrations. They were verifiable then, and given continuing advances in seismological technology, they are even more verifiable now.
>
> The quotation taken from my 1977 testimony was testimony in support of the ratification of these two treaties without reservation. That was my position then, and it is my position today.

I think it was important to get that statement by Ambassador Warnke on the record. Thank you, Mr. Chairman.

The **Chairman**. Thank you very much. The Senator from Washington is recognized.

Senator **Adams**. Mr. Chairman, I will be brief, but I think what the Senator from Maryland has said concerns all of us. He suggested that our advice and consent to these treaties as written, without reservation, is in support of presidential power in negotiating with the Soviets and these were done long ago by administrations that certainly could not be considered to be soft on Soviet relations.

So, I am concerned that we have turned the clock around 180 degrees by coming forth, not just with a reservation, but moving the other way. But, we have covered that, between the three of us.

My real question now is, we indicated that we have been militarily disadvantaged, I think that is the testimony, by observing a 150-kiloton limitation, and that there is concern the Soviets have not. Why is it not to our advantage, Mr. Holmes, to have a treaty that they have signed with a 150-kiloton limitation. At least we would then have the opportunity to accuse them in the court of world opinion of violating a treaty.

Why don't we just ratify this treaty and militarily and psychologically, or whatever word you want to put on it, place ourselves in a position that they should observe 150 kilotons. As was just indicated by the quotation from Ambassador Warnke, at least within a range of 300 kilotons or 195 kilotons, we know if they have set one off and we are, at that point, in a position to go through all of the technical arguments you want as to whether or not they have violated the treaty. Why isn't this to our advantage militarily, as well as in the court of world opinion?

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[1] See p. 15 for quotation of Ambassador Warnke by Dr. Barker.

Ambassador HOLMES. Senator, I think we obviously have a basic disagreement with Ambassador Warnke. We don't believe that we should do that, given the present uncertainties with regard to our ability to verify.

Senator ADAMS. I am talking about just the military part of it. We are observing this, and we have maybe a question of whether they are or are not now.

Aren't we better off to have ratified the treaty, and if we believe they have broken it, than to let this hang out there and if they wish to break their moratorium or do whatever they wish to do. Aren't we better off to have a treaty that limits them to what we are already voluntarily observing from a purely military point of view.

Mr. Foley.

Admiral FOLEY. I will speak only for the Department of Energy and not for General Vesser, and you can go into this in much more detail in closed session and I would suggest that, sir.

Senator ADAMS. I understand that.

Admiral FOLEY. But there is a difference in the confidence of those who design and build weapons to test to 150 KT, and those who could test to perhaps as much as 300 KT.

Senator ADAMS. But we are already at that disadvantage, are we not?

Admiral FOLEY. We are, sir.

Senator ADAMS. I am not trying to get into the details of it, but we have already taken on this burden. Therefore, why not place it on the Soviets by ratifying this treaty as it is. At that point if you feel that there is a violation of it, we can accuse them of a violation as opposed to where we are now, of simply saying, well, that's too bad, but then they say to us, "well, you didn't ratify the treaty anyway."

Mr. BARKER. Senator Adams, the Soviets do have a legal obligation to abide by the provisions of the Threshold Test Ban Treaty.

Senator ADAMS. No, I am talking about these two treaties.

Mr. BARKER. Yes, these two treaties. They have been signed by both parties. Neither party has expressed——

Senator ADAMS. Wait a minute. Isn't it kind of disingenuous to say that they have signed up and they should continue to observe the treaties while under our system we have neither rejected it or not gone ahead.

It seems to me that our argument is far more powerful if we have said that we will in effect sign up. What we are already doing militarily——

Mr. BARKER. Senator, the Soviets are exactly in the same legal position as we are with respect to the Threshold Test Ban Treaty. Both countries have signed it. Neither country has ratified it.

Under international law, as long as neither party has stated that it would not ultimately ratify a treaty, there is an obligation on the part of both parties not to undertake an act which attacks the object and purpose of the treaty.

Senator **Adams**. So, you are telling me, as long as we have signed it, why bother because both parties are bound anyway? That doesn't make sense.

Mr. **Barker**. To me and to this administration, the principle of effective verification is very important.

Senator **Adams**. I understand that.

Mr. **Barker**. And we do not want to ratify any treaty that is not effectively verifiable.

Senator **Adams**. I understand your position on that. What I am saying is, from a military viewpoint, we are already observing this and you are telling me that it needs some further process.

All I am saying is, if we formally signed up for 150 kilotons, which you say we are already bound by, what have we got to lose? And it seems to me we have got a lot to gain militarily.

Mr. **Barker**. Sir, we have nothing to gain, I think. I think General Vesser would support that we have everything to lose in the principle of effective verification.

Admiral **Foley**. Sir, I want to know what they are testing to, and if I can narrow that range of uncertainty on down to where I have a much better feel for the yields that they are testing to, then I have a much better understanding of what their design of weapons is and what they have in mind, and that range of uncertainty today is so great that it's a risk. It's a worry to us.

Senator **Adams**. And it sits out there, whether we ratify this or not, does it not?

Admiral **Foley**. That's why we, sir, have asked for appropriate verification to narrow down this range of uncertainty. That's important.

Senator **Adams**. Wait a minute. Unless we ratify and place this burden on them, and I'm not saying whether we will or will not ratify without reservation, but unless we place that burden on them we are in the same military position. In fact, we are disadvantaged because we don't have them, in effect, committed to the fact that we have said we will do by treaty what we are already doing militarily.

I just don't understand that we give that great an advantage because we've got a lot of other treaties that are coming down and going to come ahead. The comprehensive test ban and all of these in the future; this is 150 kilotons. We have had it sitting out there, done by two administrations, a long time ago.

I just don't understand what the military advantage is of our not doing by treaty what we are already doing in effect. That's all.

Thank you, Mr. Chairman.

The **Chairman**. Thank you very much. What I see here today is realy a demonstration of going two steps forward and two steps back. I guess the basic problem is, do we have two bites of the apple or one bite of the apple.

It would seem to me that with good will and a degree of enthusiasm, that the group, the working group of your people and preferably yourselves and our staffs should be able to reach some common language. I would hope that there would meet a consensus of support.

We will be meeting this afternoon to cover some of the questions we could not cover this morning in open session in room S-407 at half past two, and at that time I would imagine most of you would be at that meeting, or would it be the intelligence community.

Senator **SARBANES**. Mr. Chairman, excuse me. I want to add, Mr. Barker, one more question in light of the question put by Senator Adams.

You said that both countries, the U.S. and the Soviet Union, were under international law and obligation to adhere to the terms of the treaty although not ratified, is that correct?

Mr. **BARKER**. That is my understanding, Senator.

Senator **SARBANES**. Would adoption of the reservation that you have submitted, conditioning acceptance of the treaty to the subsequent agreements that must be submitted, lift that obligation under international law?

Mr. **BARKER**. For one, I must admit I do not know. I am not an international lawyer. Certainly no one in the administration who was involved in preparing that memo assumed that that would be the case.

Senator **SARBANES**. So, if that is the case, that was an untoward effect; it was not something that you intended to have happen, is that correct?

Mr. **BARKER**. Correct, Senator.

Ambassador **HOLMES**. Correct.

The **CHAIRMAN**. Thank you very much, Senator Sarbanes.

This meeting is recessed until 2:30 this afternoon.

[The prepared statements of Senator Adams and Senator Lugar follow:]

PREPARED STATEMENT OF SENATOR ADAMS

Mr. Chairman, I want to make a very brief comment. The people of the State of Washington know all too much about nuclear weapons: the plutonium they use is processed there, the wastes they generate are stored there. For us, then, this no abstract or theoretical geo-political strategy—they are a very real and very present part of our lives.

We are ready to do what needs to be done to protect our nation; but we want to believe that someone is doing what ought to be done to protect our future. We believe that these Treaties are a part of what ought to be done.

These Treaties have been in a state of limbo for over a decade now. But in that period, there was at least support for them by the Nixon-Ford administration and the Carter administration. Tactical considerations delayed their ratification, not doubts about their wisdon or concerns about their impact on national security. Those doubts and those concerns did not develop until the Reagan administration decided that despite advances in every other area, our verification capabilities had suffered a regression since these Treaties were signed.

Mr. Chairman, no one wants to sign a Treaty with the Soviets which cannot be verified. But these Treaties can be verified. And recent indications suggest that once they are ratified, they may serve as a vehicle for advancing our interest in promoting Soviet acceptance of on-site vertification of tests and possibly other Soviet military activities as well.

I am willing to listen to any concerns which the administration may have about these Treaties. But I want the administration to listen to the concerns of my constitutents as well. The American people are concerned about their future and worried about control. My constituents have reached the point where they want to be able to do more than verify Soviet behavior; they also want to verify the President's commitment. And they are not safisfied when they see two Treaties—which offer us some modest progress and which have been supported by previous presidents—suddenly being painted as a threat to our national interests and an unacceptable risk to our national security.

The people in the State of Washington, want to see some progress. And I believe that this Committee and this Congress are willing to do the work required to satisfy that desire while protecting the legitimate security needs of the nation. Thank you.

PREPARED STATEMENT OF SENATOR LUGAR

I would first like to congratulate my friend Senator Claiborne Pell on becoming Chairman of the Committee on Foreign Relations. America is indeed fortunate to have a man so dedicated to its service as you. I look forward to working with you, and wish you great success in the 100th Congress.

The first hearing over which you are presiding is indeed an important one. Giving advice and consent to the ratification of a treaty, especially one dealing with vital aspects of our national security, is one of the Senate's most important functions. We must fully understand the issues, and know exactly what obligations we and the Soviet Union would be undertaking in order to fulfill our role as the framers of the Constitution intended. Hearing witnesses from every concerned department of the Administration, the Joint Chiefs of Staff, our negotiators, the intelligence community, the national laboratories and distinguished private citizens is precisely the way to begin this process. Senator Pell is to be congratulated for getting us off on the right foot.

A decade has passed since the Senate examined the TTBT and PNET in depth. Therefore, we must first take the time to establish that the treaties would contribute to our security and to greater stability in our relationship with the Soviet Union. If a 150 kiloton limit on the yield of nuclear tests, along with the other obligations contained in the TTBT and PNET enhance our security, the record of our proceedings in 1987 should reflect this judgment. With this established, we must then turn our attention to what has become the central issue for these treaties, verification.

Unfortunately, the experience of the last decade has only underscored the need for effective verification. No matter how good a treaty is in theory, it cannot fulfil its function unless all sides have confidence that their partners are complying with their obligations. Confidence does not mean inability to prove that a violation has taken place; it means reasonable certainty that there is compliance. Anything less undermines the agreement and arms control in general. President Reagan must be congratulated as the champion of effective verification. For years the Soviet Union resisted even talking about additional verification measures for these treaties. But due to his persistence and effort they have now agreed to discuss the subject. Three meetings of verification experts have already been held, and Soviet leaders have recently indicated their willingness to solve the TTBT and PNET verification problem. What we do in the Senate must strengthen the President's hand in this endeavor.

I am confident that with a thorough understanding of nuclear testing issues and the greater strategic issues surrounding them, this Committee can recommend to the Senate a course of action which leads to ratification of a verifiable TTBT and PNET. I look forward to working with Senator Pell and all my Committee colleagues in this first challenge of the 100th Congress.

[Whereupon, at 12:40 p.m., the hearing was adjourned to reconvene at 9:34 a.m. on Thursday, January 15, 1987.]

THRESHOLD TEST BAN TREATY AND PEACEFUL NUCLEAR EXPLOSIONS TREATY

THURSDAY, JANUARY 15, 1987

U.S. Senate,
Committee on Foreign Relations,
Washington, DC.

The committee met at 9:34 a.m., in room SD-419, Dirksen Senate Office Building, Hon. Claiborne Pell (chairman of the committee) presiding.

Present. Senators Pell (presiding), Sarbanes, Zorinsky, Kerry, Simon, Adams, Moynihan, Pressler, and Trible.

The Chairman. The Committee on Foreign Relations will come to order.

I would like to extend a warm welcome to the witnesses this morning at our third hearing on the question of ratification of the 1974 Threshold Test Ban Treaty and the 1976 Peaceful Nuclear Explosions Treaty.

Shortly before the Iceland summit, President Reagan assured the Congress, as part of a compromise on the testing issue, that if he could conclude a verification agreement with the Soviet Union, he would ask the Senate to approve the TTB and PNE treaties.

If such an agreement could not be concluded, he said he would still make ratification a first order of business, but with a reservation to ensure that the treaties do not take effect until they are effectively verifiable. The President said he would work with the Senate in drafting the reservation.

Following up on that idea, I asked the Committee staff of both parties to work with representatives of the Administration in an effort to develop language that we could put before the Committee for its consideration. That process is still underway.

However, at our first hearings on Tuesday, Administration witnesses put forward their position that the Senate should only consent to ratification of the two treaties subject to the condition that the President shall not proceed with the ratification until he certifies that he has additional agreements with the Soviets requiring direct, accurate on-site monitoring of all appropriate tests so that the treaties are effectively verifiable and—I repeat, and—until the Senate has advised and consented to the additional agreements.

The process the Administration proposes is one which would make Senate consideration in the first phase really little more than a charade and a waste of the Committee's time.

On the basis of the discussions at the Committee Tuesday, at which concerns were raised by Senators of both parties, our staffs are now putting together options to be weighed by the members. I hope that this can lead to more productive discussions with the executive branch.

I also hope that an approach can be devised which gains wide bipartisan support, ensures that the Senate action will be decisive, a single action, and promote arms control progress while protecting our national security interests.

As I see it, we must weigh the options of moving toward consent to ratification of the treaties as they were submitted in 1976, of seeking additional verification arrangements before consenting to ratification, or of specifying any verification arrangements to be achieved prior to ratification.

In addition, the Joint Chiefs of Staff have asked that certain safeguards be adopted. Certain safeguards were specified in connection with consent to ratification of the LTB treaty in 1963, and the Chiefs seek similar, but revised, safeguards now.

The Chiefs seek "continued underground nuclear test programs consistent with treaty limitations, maintenance of modern nuclear laboratory facilities, maintenance of the basic capability to resume nuclear tests in prohibited environments and yield ranges, should they be considered essential, a vigorous verification program, and continued emphasis on intelligence capabilities."

The Joint Chiefs are also asking for "the conduct of an independent U.S. governmental review at periodic intervals to determine if renewal of the treaties is in the United States 'national interest.'

The witnesses today are well qualified to deal with the questions we must address. Our first witnesses are the directors of the two nuclear weapons design laboratories: Dr. Roger Batzel, Director, Lawrence Livermore National Laboratories; and Dr. Siegfried Hecker, Director of Los Alamos National Laboratories.

Following their presentation, the Committee will hear from: the Honorable William Colby, former Director, CIA; Dr. Wolfgang Panofsky, Director Emeritus of Stanford Linear Accelerator Center and Professor at Stanford University; Dr. Milo Nordyke, Leader, Treaty Verification Research Program, Lawrence Livermore National Laboratories; and Professor Paul Richards, Lamont-Doherty Geological Laboratory, Columbia University.

At this point, I would ask Dr. Batzel and Dr. Hecker of they would care to start. Dr. Batzel.

STATEMENT OF DR. ROGER E. BATZEL, DIRECTOR, LAWRENCE LIVERMORE NATIONAL LABORATORIES

Dr. Batzel. Thank you, Mr. Chairman.

I come back to this committee after about 10 years to the same discussion we had in the summer of 1977 about this same treaty. Much of what I have to say now I said then. But I come today with some different views than I had at that particular time.

The Chairman. Well, I know my memory fades on what you said ten years ago, but I recall that it was very good.

Dr. Batzel. I have a written testimony which I would like to submit.

The Chairman. That will be inserted in the record as if read, without objection.

Dr. BATZEL. As noted, our national security certainly depends on the deterrence of war and the necessary presence of nuclear forces at this stage. Those nuclear forces and the in maintenance are the responsibility of the two nuclear weapon laboratories, directed by Dr. Hecker and myself.

As directors of those laboratories, it is also our responsibility to be sure that nuclear weapons technology in this country does not lag that of our potential adversaries.

There is the widespread, though incorrect, perception that somehow nuclear weapons testing fuels the arms race. I think this is contrary to the facts. The current U.S. nuclear weapons program, and its experimental capability which involves nuclear weapons testing, is already being conducted under a number of limitations, namely, the Limited Test Ban Treaty and the Threshold Test Ban Treaty. In spite of these limitations we believe we have been successful in carrying out the major parts of our commitments to the country in weapons technology.

Modern nuclear weapons are complex technical devices which have been optimized and carefully integrated into overall weapons systems. The conditions under which these weapons operate are unique, almost unique in the universe. We cannot take all of the information—and we try very hard—take the information measured by non-nuclear means and extrapolate into the nuclear weapons performance regime.

There are basically four reasons why we have nuclear tests: First, we test to maintain the proper functioning of the stockpile of weapons we currently have;

Second, we test to modernize the existing stockpile of weapons for enhanced safety, security, and effectiveness;

Third we test to measure the effects of a nuclear weapons environment on our weapons systems;

And finally, we test to avoid technological surprise. There is no reason to believe, that the nuclear weapons technology of the Soviet Union trails that of the United States.

As far as stockpile modernization is concerned, the test program of the U.S. has been aimed in a major way at safety, security, and in fact has led to a reduction in the number of U.S. nuclear weapons by approximately 25 percent, and in the total destructive power and yield of the stockpile by a factor of about four, since their peak valves in the 1960's. This reduction would not have been possible without nuclear weapons testing.

It is important to understand that this upgrading and work on the existing stockpile is important to our nuclear deterrent in terms of the flexibility that it provides and in terms of the disposition of our nuclear forces. And it certainly is important because the global strategic balance is a dynamic, not a static situation.

We can meet our current military requirements and do weapons physics research that we deem to be appropriate and necessary within the 150 kiloton limit. However, we are constrained with respect to certain kinds of warheads which may be important to the United States.

The constraint has to do with the necessity for tests above 150 kiloton level. In fact, for some of the advanced weapons we are looking at, it would be useful to have the flexibility of testing at the 300 kiloton level, a yield that lies at the upper end of the uncertainty which exists for seismic monitoring of the Threshold Test Ban Treaty.

So there are nuclear design advantages to testing in the 300 kiloton regime.

In assessing what benefit there might be to the Soviet Union if they had the flexibility of testing at 300 kilotons, we have to mirror image the situation. Then I would come to the conclusion that, while we have so far been able to meet our major commitments without testing above 150 kilotons, we could assume, that they have done similarly. However, mirror imaging is a difficult way to approach the situation. We just do not know that much about the details of the Soviet nuclear weapons program. So it is quite possible that for them the ability to test above 150 kilotons could be quite important.

Verification of the Threshold Test Ban Treaty is another issue and I think I discussed verification the last time we were here. My expectation 10 years ago was that seismic verification was all right because we did not have an alternative.

Today we believe we have an alternative which would allow more precise of measurements, better measurements, to within say 30 percent. From a nuclear design point of view, that certainly constrains what the Soviet Union could do without being detected.

I believe seismic monitoring, a problem we have worked on at my laboratory, does not leave us in a very viable situation in the long term, because one can construct situations where the Soviet Union, by careful choice of geological structure, and by taking advantage of the other uncertainties of seismic methods, could in fact test at yields which are considerably above the 150 kilotons. We cannot prove that.

From the nuclear weapons point of view, I think the ability to evaluate and confirm that the Soviet Union is staying within, say, 30 percent of the 150 kiloton limit would leave the United States in a stronger relative position.

In conclusion, my bottom line is that for the foreseeable future safe, secure, reliable and survivable and effective nuclear weapons will remain a critical element in the stability of the strategic balance, and nuclear weapons tests are going to be fundamental to the continuation of that capability.

Thank you.

[The prepared statement of Dr. Batzel may be found in the appendix.]

The CHAIRMAN. Thank you very much, Dr. Batzel.

Dr. Hecker.

STATEMENT OF DR. SIEGFRIED S. HECKER, DIRECTOR, LOS ALAMOS NATIONAL LABORATORY

Dr. HECKER. Thank you, Mr. Chairman.

I welcome the opportunity to present to the Committee my views on the TTBT, the PNET, and some aspects of improved verification. With your permission, I would also like to enter a written statement into the record.

The CHAIRMAN. Without objection, that will be done.

Dr. **Hecker**. Thank you.

As pointed out by Dr. Batzel, we, the two laboratory directors, and only we have the responsibility for certifying the nuclear weapons. Certification of weapons performance must hold for the entire life cycle of the weapons.

We must also assure the safety of these weapons, and we must constantly guard against technological surprise by potential adversaries.

Since nuclear weapons performance is a key to credible deterrent and since the security of the United States and the security of the free world currently depends on that deterrent, I believe you will agree that indeed the lab directors have been asked to shoulder a grave responsibility.

We have accepted that responsibility willingly and, I might add, also with great pride. However, to do this job well we need certain tools. First of all, we need first rate scientists and engineers, dedicated to national defense, and fortunately today we have these at the two DOE nuclear weapons laboratories.

Secondly, we need the ability to conduct nuclear tests. Nuclear testing is indispensable for the life cycle of a nuclear weapon, all the way from design through the maintenance of the stockpile.

As mentioned by Dr. Batzel, the behavior of nuclear weapons is so complex that today we cannot completely model that behavior by computer, nor can we adequately explore that behavior with non-nuclear laboratory experiments. We always have, and in the foreseeable future we always will have, to require nuclear testing to calibrate these models and to calibrate these tests.

Also, nuclear testing will continue to help build the confidence of our nuclear weapons designers. It is their judgment that is really indispensable, not only in design but also in production, and also to answer reliability questions that inevitably arise during the lifetime of a nuclear weapon.

And as long as I am responsible for weapons that are already part of the deterrent forces, and as long as the dynamics of the world politics dictate new military requirements for nuclear weapons, I foresee the need for nuclear testing.

Restrictions on testing, including those that we presently observe under the TTBT, make the job of assuring this nation's deterrent a more difficult one. All such restrictions carry technological risks. These risks may translate into military risks, or at least into military penalties.

I consider it my responsibility to bring these technological risks to your attention. Then you and other policymakers must judge the tradeoffs between these technological risks and any benefits resulting from such restrictions.

Let me turn specifically to the TTBT. Before signing the TTBT treaty in 1974, MIRV'ed missiles and greater missile accuracy had reduced the overall DOD requirement for U.S. strategic forces. The 150 kiloton limit at that time appeared restrictive, but manageable.

During the 1977 hearings on this treaty, one of my predecessors as Director of Los Alamos, Dr. Harold Agnew, voiced the following caution:

> If you believe that there will be requirements for new, untested designs at yields considerably larger than 150 kilotons, then if the treaty is ratified our defense sys-

> tems eventually will have to bear a penalty in payload, weight, physical size, and perhaps even an additional use of fissile materials. These penalties will accrue because under the treaty the high-yield warheads of the future will of necessity be the same ones that had been developed in the past.

Indeed, since that time in 1977, an aggressive Soviet program to harden and-or bury their prime targets and threats prompted our military to require higher yield weapons to assure a credible deterrent. Most of our strategic weapons currently fall into this category.

Whereas weapons design and certification used to rely on judgment that was directly based on full yield tests of newly weaponized systems, we have not been able to do so in the past ten years. We have been faced with designing and certifying new weapons at yields significantly higher than the 150 kiloton test limit.

And, as Dr. Agnew predicted, the designs we chose for those high yield weapons were not entirely new. They were based on tests conducted prior to March 1976. And in fact, a single earlier test has really served as a particularly important reference test to many of these systems. This test or any others like it cannot now be repeated.

Hence, weapons certification now rests heavily on old tests and on indirect evidence that we gather from limited partial yield tests that are interpreted by skilled weapons designers.

So to keep our confidence level up for certification, of higher-yield weapons as we certainly must, we have then adopted more conservative designs, designs based on old, tested technology. We have relied more heavily on stockpile confidence tests, albeit of modified devices at partial yield. And we have relied even more heavily than before on the judgment of skilled, experienced weapons designers.

I spoke earlier of the technological risks and potential military penalties of testing restrictions. I believe that in the past ten years under the TTBT restrictions we have met the necessary military requirements, even though the new, high-yield weapons requirements were not explicitly foreseen in 1974. And moreover, we have kept the risks and penalties manageable, as I have just described.

Let me point out, however, that I would not be able to say that we have met our responsibilities if the yield limit for tests had been significantly lower over the past decade. Nor would I be able to say a decade hence that we had been able to meet these requirements unless there are fundamental changes to the nuclear deterrent.

Also, I am genuinely concerned, as Dr. Batzel also enumerated, that continued Soviet hardening or burial actions will bring about new military requirements, requirements that are needed for a stable deterrence that may prove beyond the reach of old or tested design technologies.

And I should add that these Soviet actions do not necessarily entail nuclear testing on their part. Yet, they can dramatically shift the nature of deterrence.

Let me now turn to the question of verification. The importance of verification of compliance has been stated many times during these hearings. From my perspective, it is important that neither side can gain a significant military advantage through clandestine violations.

The current treaty provisions in my opinion do not meet this requirement. Much controversy exists over past Soviet compliance with the 150 kiloton limit on the basis of the U.S. interpretation of teleseismic signals from Soviet tests.

The evidence and interpretation in my opinion are inconclusive. The pattern of Soviet testing is consistent with substantial compliance, but, most importantly, it is also consistent with significant violations.

So what is most important, then, and more important than the controversy over past compliance, is really how can we effectively verify compliance in the future?

At our laboratory, we have carefully analyzed the statistical evidence of teleseismic signals and conclude that the ability to conduct tests at the level of 300 to 450 kilotons at least occasionally cannot be denied to the Soviets under the present treaty provisions, which rely on seismic measurements having statistical uncertainties.

On the other hand, the United States has scrupulously complied and will continue to comply with the 150 kiloton limit. So we must now ask if this asymmetry is really of military significance.

In 1974 the answer was uncertain, because the Soviets concentrated on weapons systems in the megaton yield range. But now, since they have adopted MIRV technology, their systems appear to be closer to the 500 kiloton range, one that is also of interest to the United States.

So the bottom line is that the Soviets can test occasionally close to a yield that is very important to the development of nuclear weapons of great military significance to both countries, and the U.S. cannot. So improved verification must be sought so that the same burden is placed on the Soviets.

This would be a specific benefit of the ratification of these treaties with improved verification, a benefit that is currently denied by the status quo.

Today the best way that we can assure significantly improved verification is with on-site measurement of the hydrodynamic yield, the CORRTEX method which has been discussed previously at these hearings. As pointed out then, this method is the one the President has proposed to the Soviets for improved verification.

I would just very briefly remind you that this method requires the other country be allowed to be present on site at the host country's test site to monitor signals from an adjacent hole drilled close to the emplacement hole containing the nuclear device.

Much of the protocol for such on-site monitoring was developed for the PNET during the discussions in the seventies. In the past few years, we at Los Alamos have worked the problem of applying this method for weapons test verification under the 150 kiloton limit. There are new concerns for weapons tests which include those of not interfering with the test objectives and not compromising sensitive classified information.

I believe that we have now dealt with these problems successfully and we are confident that indeed CORRTEX reduces the uncertainty of yield measurements to a factor of 1.3, (or 30%) compared to that of approximately a factor of two for teleseismic. In my opinion, that represents the best way to deny the Soviets continued advantage under the TTBT.

So in summary, I favor ratification of the TTBT and PNET with the provisions of improved verification. The United States should insist on a verification protocol that does not allow the Soviets to test at a level above the threshold limit at which they can achieve a militarily significant advantage.

It is important to reiterate that all testing restrictions lead to some technical risks and potential military penalties. The TTBT restrictions to date have been manageable, although I have some concerns about the future. Testing constraints more restrictive than those proposed in the TTBT would greatly endanger our ability to adequately support the nation's deterrent in terms of safe, secure, reliable and effective nuclear weapons.

I would like to urge that any such constraints are considered only after carefully looking at this nation's policy of nuclear deterrence. That is, it is imperative in my opinion that we work the nuclear weapons issue by starting with nuclear weapons policy for deterrence, followed by arms control, and then followed by nuclear testing considerations, rather than the reverse, which currently appears to be the case.

Thank you, Mr. Chairman, for giving me this opportunity to express my thoughts to the Committee.

[The prepared statement of Dr. Hecker may be found in the appendix.]

The CHAIRMAN. Thank you very much indeed. And as I said earlier, your full statement will be inserted into the record.

Now, you are familiar with the proposed Joint Chiefs safeguards, am I correct in that?

Dr. BATZEL. Yes.

The CHAIRMAN. You have those?

Dr. BATZEL. Yes.

The CHAIRMAN. Could you tell us the extent to which you believe the specified safeguards are being met right now at this time?

Dr. HECKER. I am sorry? You have asked as to how the safeguards are being met?

The CHAIRMAN. Whether the safeguards are being met at this time.

Dr. BATZEL. Well, as far as safeguard A is concerned,

> The conduct within the constraints of existing treaties of nuclear testing and comprehensive, aggressive, and continued underground test programs designed to add to our knowledge and improve our weapons in all areas of significance to our military posture for the future.

I would say that we are conducting our nuclear weapons testing within the constraints of those treaties.

I would say the underground nuclear weapons test programs certainly have the potential of being very aggressive. I believe the current program, while adequate, is not aggressive.

Regarding the safeguard calling for the "maintenance of modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology which will attract, retain, and ensure the continued application of our human and scientific resources to those programs on which continued progress on nuclear technology depends," I would say we are not in bad shape in that particular regard.

Certainly the recognition of these needs and commitment to making sure we have those facilities, specifically additional facilities, would be useful.

As far as safeguard C is concerned, "the maintenance of the basic capability to resume essential nuclear test programs in prohibited environments and to conduct testing promptly in prohibited yield ranges," should such tests be deemed essential to our national security, as far as that situation is concerned, it would take time to prepare facilities to test in the prohibited yield ranges. It is possible to do that but it takes time.

As far as our ability to conduct tests, for example, in the atmosphere, again that we could respond to that, but it would take time.

The CHAIRMAN. And safeguards D, E, and F?

Dr. BATZEL. Safeguards D, E, and F. Safeguard D,

> In conjunction with a vigorous verification program, the conduct of a comprehensive and continuing research and development program to improve our monitoring capabilities and operations, with the goal of providing high confidence in monitoring of those actions from which non-compliance with existing nuclear testing treaties could be inferred.

I think we have that. I think we have a method today in CORRTEX which is the consequence of those efforts. It is available to us. It needs to be applied.

Safeguard E,

> The continuing development of a broad range of intelligence gathering and analytical capabilities and operations to improve our knowledge of the nuclear arsenals, nuclear weapons development programs, related nuclear programs, and the capabilities and achievements of the Soviet Union and other nations.

I am familiar in some detail with the intelligence related to nuclear weapons technology. I believe we have worked that problem pretty hard. We do not see very far into the nuclear weapons technology of the Soviet Union. They hold that very closely. We see very little of what they are doing. Past experience and past knowledge was based on atmospheric tests, in the early sixties, for example. Since that time, we have gotten very little insight into that. Certainly we need to continue to work that particular problem.

Safeguard F, "the conduct of a governmental review at periodic intervals to determine whether continuing compliance with the provisions of existing treaties on nuclear testing is in the U.S. national security interest." I certainly believe that such reviews periodically are important. I certainly endorse that.

The CHAIRMAN. Good. I thank you very much for your response. Dr. Hecker?

Dr. HECKER. Mr. Chairman, may I also respond briefly to these?

The CHAIRMAN. Certainly. And I would ask unanimous consent that we insert into the record at this point the full text of the safeguards.

[The material referred to appear in the appendix.]

Dr. HECKER. I would just like to respond briefly. In terms of safeguard A, I agree with Dr. Batzel that indeed we are taking care of that safeguard now within the constraints currently imposed on nuclear testing. Indeed, we are conducting a vigorous program to try to understand better the nuclear weapons and take care of the military posture.

Regarding safeguard B, I think the nuclear weapons laboratories currently are in good scientific shape. I am certainly concerned that they stay that way in the future.

In safeguard C, I agree again with Dr. Batzel that it certainly would take time to establish those.

And safeguard D, certainly I think one could encourage further research in the whole area of monitoring and verification.

And safeguards E and F I think are more appropriate for someone else to answer than myself.

Thank you.

The CHAIRMAN. Thank you.

Are there any proposed safeguards not now in effect that you think should be brought into effect? Dr. Batzel?

Dr. BATZEL. My impression is that this covers those areas which would be of concern.

The CHAIRMAN. Thank you.

Dr. Hecker?

Dr. HECKER. I think this covers it quite well. The main concern that I would have, as I have brought out in my testimony, is that indeed we keep competent, experienced designers at the laboratories to help us out in the nuclear weapons program. I think these safeguards would allow us to do so.

The CHAIRMAN. In general, would both you gentlemen support the specification of these safeguards? Would you change this in any way, or do you think we are about right the way we are?

Dr. BATZEL. I think they are about right the way they are.

Dr. HECKER. I have not studied them really carefully, but they seem adequate.

The CHAIRMAN. Now, you both obviously are very familiar with the Administration's plan for the on-site monitoring. And as I understand your earlier testimony, you are in full agreement with that, is that correct?

Dr. BATZEL. We certainly believe that use of CORRTEX in the on-site monitoring and measurement of yield is fundamentally important.

Dr. HECKER. It would at this point give us the opportunity to really reduce the uncertainties to a level that I think are acceptable to the United States.

The CHAIRMAN. Do you have any reservations with regard to the CORRTEX system beyond the 30 percent unreliability?

Dr. BATZEL. The reservation has to do with making sure that the situations in which these measurements are made are not compromised by modifications of the test configurations, and that restrictions be placed on the manner of conduct of the nuclear test.

Dr. HECKER. I think it is unfortunate that CORRTEX has received some unfavorable press in the past few days. I would say that we have worked very hard to try to take care of those reservations and at this point feel comfortable that indeed the increased accuracy is there and that we can treat the issue that Dr. Batzel just mentioned, worrying about the intrusiveness.

The CHAIRMAN. Do either of you have any reservations with regard to accepting the provisions now being discussed with regard to our own, your own, Nevada test site? If so, what would be those reservations?

Dr. BATZEL. Reservations? I'm sorry, sir?

The CHAIRMAN. Do you have any reservations with regard to accepting the provisions now being discussed at our own Nevada test site?

Dr. BATZEL. I have no reservations, given that it cuts both ways.

Dr. HECKER. I have none.

The CHAIRMAN. Thank you.

Now, if I could ask you a layman's question, I don't understand, and maybe you could explain it in more layman terms, what the great significance is if you can test 150, 300, or 500 kilotons. Can you sort of reduce that into non-classified layman terms?

Dr. BATZEL. It is very difficult to do in an unclassified way. We need to have the opportunity to discuss with you what the configurations are and why these particular yields do limit our ability to extrapolate. It is a question of how far one can extrapolate the information derived from a nuclear experiment.

We feel reasonably comfortable with a factor of two for some nuclear explosives. For others, 50 percent, one and a half times, or even one and a quarter times, could be a complication. So it is not a universal formula, and one has to look at each nuclear explosive separately.

The closer we can come to the required yield in terms of a nuclear test, the more comfortable we are with respect to extrapolating and the more confidence we will have in that warhead.

The CHAIRMAN. I thank you. And this is a question I really would like answered. Maybe we could go into the back room to answer it in a classified why, or if you would like to submit a statement, a classified statement, at this point explaining it. Either way would be agreeable to me.

Dr. BATZEL. It might well be better to actually discuss it with you, to make sure that we understood one another and are communicating properly.

The CHAIRMAN. When we are through with our open sessions, we will slip into the back room for a moment.

Senator Simon.

Senator SIMON. I would like to join in that meeting and get that layman's description.

Dr. Batzel, my staff tells me that in March 1985, shortly before the Soviets stopped testing, you testified before Congress that "the Soviets appear to be observing a yield limit consistent with TTBT compliance." Is there any reason to change that testimony?

Dr. BATZEL.They do appear to be observing a limit. I think the statement as you have stated it stands. The uncertainties are large enough that they appear to be conducting their tests within those limitations. I would certainly be more comfortable if the limits of the error were narrower than they are today.

Senator SIMON. And what do you say those limits are? In other words, is it the factor of two that has been tossed out?

Dr. BATZEL. It is presently on the order of a factor of two. That means, as was pointed out the other day, at 150 kilotons your measurement can say that it is 75 or 300. The flexibility to test at 300 kilotons is significant.

Senator SIMON. The New York Times of Tuesday has an article written by Michael Gordon which includes this statement:

> Some experts say CORRTEX is not a useful technique for measuring explosions of less than 50 kilotons and that the Administration's exclusive reliance on it may reflect an underlying hostility to negotiating substantially lower limits on the size of tests. They say the new seismic monitoring measures could monitor small tests.

I would be interested in the response of either of you. Is that accurate?

Dr. HECKER. I would like to tackle that question, if I may. Certainly the statement that CORRTEX is not useful below 50 kilotons is not true. Indeed, we have used CORRTEX for many smaller tests, in fact in the sub-kiloton range. It is true, however, that as the yields get lower and lower all of the methods become more and more doubtful. However, CORRTEX can be used effectively below the 50 kiloton range.

Senator SIMON. What about when the article says "they"—that is, the experts—"say the new seismic monitoring measures could monitor small tests"?

Dr. BATZEL. The inherent uncertainty, which is now a factor of two at 150 kilotons, is going to be larger for seismic at the lower yields.

Senator SIMON. And the CORRTEX would be more accurate than the seismic tests on those lower yields?

Dr. HECKER. It is really complex enough that you would need to talk specific yield ranges, and you would have to remember that it is not just a question of measurement in terms of verification; it is a question of measurement and identification.

Indeed, with CORRTEX, if it were accepted, it would be such that it would be used above some lower threshold limit, and the identification problem would be solved. Below that problem, you indeed with the seismic have the problem of being able to first measure, and indeed, one can measure it down to low levels, but then be able to identify. And that identification is the really difficult part.

So what we have done is we proposed CORRTEX to look at the compliance issue of the 150 kiloton limit. We have not proposed CORRTEX for the overall identification or verification method, because clearly you need to be on site. So you are really comparing apples and oranges.

Senator SIMON. So the seismic tests tell overall whether an explosion has taken place. The CORRTEX goes to a specific site or a specific area.

Dr. BATZEL. Yes, it is used in a specific location and is attached to a specific nuclear weapons test.

Senator SIMON. So you would not have to have these CORRTEX sites or whatever you want to call them——

Dr. HECKER. No, absolutely not.

Senator SIMON [continuing]. All over the Soviet Union in order to have compliance?

Dr. BATZEL. The CORRTEX measurement has to be done only within say a few feet of the nuclear explosion itself.

Senator SIMON. So that practically what happens is the Soviets would notify us they are going to have a test at site A, and then you would have the CORRTEX there; is that right?

Dr. **Batzel**. For example, if the test by the Soviets is in a vertical hole in the ground which they have drilled, you would drill a parallel smaller hole, in which you would emplace the electronic gear which allows you to measure the position of the shock wave which is a consequence of the explosion, as a function of time and then derive information about the yield of that explosion.

Dr. **Hecker**. If I may just add one point which may help to clarify, the two methods really need to be used in a complementary fashion. That is, the lower yield tests, to be able to detect them at all one needs to do it seismically, because there is no universal CORRTEX network, as you say.

Then above a certain yield range, for specific tests then one can use CORRTEX to increase the accuracy.

Senator **Simon**. Thank you.

Finally, Dr. Batzel, first of all, I would disagree with a few of your conclusions. You talk about the "so-called arms race." Those of us who are voting appropriations, I do not think any of us think there is a so-called arms race. There is an arms race, period.

You say there is a widespread, though incorrect, perception that nuclear testing fuels the arms competition between the superpowers. I am among those who believe that is correct, that that does fuel it.

Then you say, we test for four basic reasons. We test to maintain the proper functioning of the stockpile of weapons we currently have, we test to modernize, we test to measure the effects, and the last is basically measuring the effects also.

If both sides have some uncertainty about their nuclear weapons, is that not, rather than constantly improving and modernizing and making every weapon so much more powerful so that it can reach them in so much less time and everything else—are we not in a safer world if both the Soviets and the United States have some uncertainty as to whether their nuclear power works, so that you do not have that first strike potential?

Dr. **Batzel**. The issue with respect to uncertainty and confidence level in nuclear weapons and the nuclear deterrent that is a military issue. And I think one can make the argument on both sides. One can argue that if you are uncertain about your capability you want more. One can make the argument that if that uncertainty is there you would be afraid to use it.

My worry is that what that does is place a great emphasis on doing a single test, for example, to verify that a system works in order to be able to use it. So it gets to be a very complicated kind of discussion. I do not think there is any obvious, clearcut answer.

Dr. **Hecker**. Senator, may I try to respond from my point of view?

Senator **Simon**. Yes.

Dr. **Hecker**. I firmly believe that the uncertainty needs to be as small as possible in order to keep the deterrence as credible as possible. I believe that as the credibility of each side's deterrent increases, then the probability of use decreases.

And so uncertainty, if anything, may actually have the military want to acquire more weapons and have them try to use these weapons in a situation where they maybe should not. And so I think it is extremely important to keep the uncertainty as low as possible.

Senator SIMON. May I reverse it? Let us say there is a growing uncertainty on both sides. And my time is just about up here. Does not that make it less likely that there is a first strike by either of the superpowers?

Dr. HECKER. If there is no uncertainty, I think you have stable deterrence and no first strike.

Dr. BATZEL. I believe it is very difficult to evaluate the uncertainty in another nation's nuclear deterrent. You have to know in greater detail than I think we are going to know what that level of uncertainty might be.

Senator SIMON. I thank you both.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

I am through with my questions. Are you through with yours, Senator Simon?

Senator SIMON. I am.

The CHAIRMAN. Then let us go into the back room for a few moments if we may. The committee will recess or will adjourn to the back room for a moment and we will be back in a quarter of an hour, 20 minutes, I hope.

[Whereupon, at 10:25 a.m., the committee proceeded in closed session.]

[Whereupon, at 10:55 a.m., the committee proceeded in open session.]

The CHAIRMAN. The committee will come to order.

We now come to panel number two, consisting of: the Honorable William Colby, former Director of the CIA—would you please come forward—Dr. Wolfgang Panofsky, Director Emeritus of the Stanford Linear Accelerator Center at Stanford; Dr. Milo Nordyke, Leader of the Treaty Verification Research Program at Lawrence Livermore Laboratories; and Professor Paul Richards of the Lamont-Doherty Geological Laboratory at Columbia.

Would they please come forward and sit here at the witness table.

Senator PRESSLER. Mr. Chairman, while the witnesses are coming forward——

The CHAIRMAN. The acting ranking minority member is recognized.

Senator PRESSLER. Thank you, Mr. Chairman.

Let me welcome the witnesses. I have two amendments regarding verification that I will be offering, and they will require roll call votes. But I was wondering, what is the Chairman's disposition? Hopefully, we will get the ranking minority membership taken care of in our caucus Tuesday morning.

What is the best timetable now for this?

The CHAIRMAN. Well, we have had to postpone the markup on the PNET and TTBT treaties. We have not yet fixed on a date. That will be dependent upon the settlement of who is the ranking minority member.

Also, we must get our ducks in order on both sides as to what our own positions are. So I would say that the possibility of a markup on the treaties is unlikely next week, but we will do our best. Certainly it will not be Tuesday, as scheduled.

Senator PRESSLER. Thank you. When we do have it, I have two amendments regarding verification that I will be offering.

The CHAIRMAN. I thank you very much for putting us on notice in this regard.

Now, I apologize to the witnesses for the delay and would suggest we get started. We will follow the ten minute rule with Senators, and I would hope the witnesses also might basically observe that.

Your statements will be inserted in full into the record. I am not sure how you would start out. I would say the Princeton graduating class of 1940, Mr. Colby, should start out.

STATEMENT OF WILLIAM E. COLBY, MEMBER OF THE BOARD, COMMITTEE FOR NATIONAL SECURITY, DIRECTOR OF CENTRAL INTELLIGENCE 1973-76

Mr. COLBY. Thank you, Mr. Chairman, for inviting us to come to this meeting and to express our views.

Let me first put my position clearly, that I favor the ratification of both treaties without reservation as they stand. I think it is important that we do so. The question is always asked about verification. This always comes up on these treaties.

Before you talk about verification you really have to think, what is the purpose of verification? Is it to get evidence to use in a court of law to establish a case beyond a reasonable doubt? No. It is to protect our country, so that we can be aware of dangers which are arising to our country.

Now, when you think of it in those terms you realize that we are verifying or monitoring Soviet developments in this kind of weaponry whether we have a treaty or not. We have to do it every day, and we do an extremely good job.

As you look at the Department of Defense annual publication about Soviet military forces, you see there detailed descriptions of weapons systems and forces that the Soviets believe are most secret. We have not had a strategic surprise in this field since Sputnik, really, and we have had ample prior warning of any developments that look as though they are things that could threaten us.

I think that is the stand that you start with. The fact is that the treaties make the process easier rather than more difficult. These two treaties have a number of provisions in them that call for active cooperation by the Soviets so that we can better understand what they are doing: the limitation of the threshold treaty to certain test sites, the arrangements for inspection teams in the peaceful uses-treaty, and a variety of other provisions.

So we have to say then that the treaties will make this process of following Soviet weaponry much easier than without them.

Third, I think it is important—and I will let my fellow witnesses testify in detail on this—that there have been very substantial improvements in our ability to detect nuclear explosions over the past years while these treaties have been in effect: various improvements in technology, various improvements in seismology, various improvements in our analysis of these kinds of explosions.

And it is generally thought among most people that we can identify an explosion down to something like ten kilotons or less from outside the Soviet Union without even having people in there.

We also have had visits. We have this team in there now measuring the geology of the country, which is helping us. We have improved a variety of ways of our coverage of this.

What we considerd in 1976 as adequate verification certainly is much better today. There is no question about it. And the evidence over the years since then has shown two things:

It has shown that the Soviets have essentially complied with the treaty, despite these arguments about a few tests being over the limit; and that we have accounted for a very substantial number of Soviet explosions. So we certainly have not had any startling development that has shown that we were hoodwinked over this period.

Now, the proposal is now raised to require the use of the CORRTEX system—and we are once again off on a technological fix as being the panacea to solve all our problems. I will leave a discussion of that to the experts, but I think we have to go back to the question of whether we are going to sacrifice these treaties in order to get some technological gadget in place or are we going to get the benefit of these treaties, knowing that our present systems of verification and what is included in the treaties certainly are adequate to protect our country.

President Reagan has said there is no such thing as absolute verification, and he is right. That is certainly true. Therefore, the question is not whether we have perfect verification; it is whether we have reasonable, adequate, and sufficient to protect our country.

Intelligence, Mr. Chairman, is somewhat like a jigsaw puzzle. You know, Mr. Chairman, from using jigsaw puzzles that you can see the picture on the puzzle long before you have put the last piece in. If we are going to sacrifice the better picture that these treaties offer by insisting on every last piece of the jigsaw puzzle, I think we are going to make a mistake.

We have made these mistakes in the past. We have had arms control agreements founder on questions about verification. In 1963 we were debating a comprehensive test ban and the positions of the two sides were that the Soviets insisted that we not have more than three inspection teams a year, whereas the American position was one of having seven. Negotiators since that time have told me that in fact some Americans in high policy centers were prepared to go down to five. And a Soviet negotiator has since said that they were prepared to go up to four.

The difference between four and five is one of the major factors that led to the failure of that treaty. Now, when you think of the things that would not have developed in nuclear weaponry since that time, I think we have to say that the treaty would have made us safer, rather than exposed us to greater danger.

We face the same thing here. If these treaties are not adopted because of an insistence upon CORRTEX as a technological fix, we are going to see developments of more and more kinds of warheads.

The **Chairman**. Excuse me. I must interrupt at this point because we have to go into a short business meeting or we will lose one of our members if we do not.

This concerns the question of the budget which we must present either on the 28th or 29th.

Senator KERRY. Mr. Chairman, before you go into that, may I just ask the Chair's permission to submit questions in writing and to keep the record open?

The CHAIRMAN. Absolutely. The record will be kept open for the insertion of the new materials the Senator wishes.

Senator KERRY. May I also ask that an article from the New York Times regarding the CIA measurement of atom testing be included in the record, the transcript of a debate with the Assistant Secretary of Defense, Mr. Perle, and a number of seismologists be included in the transcript, and an article and letter by Dr. Roy E. Kidder regarding the issue of testing for reliability?

The CHAIRMAN. Without objection, they will be included in the record.

[The material referred to appears in the appendix.]

[Whereupon, at 11:05 a.m., the committee proceeded to other business.]

[Whereupon, at 11:15 a.m., the Committee resumed its open hearing.]

The CHAIRMAN. Mr. Colby, I apologize to you and to the others for the delay.

Mr. COLBY. No problem, Mr. Chairman. Thank you.

I wish to make it clear again that I believe these treaties should be ratified now without reservation. I think the President's request for a reservation is bad constitutionally, it is bad diplomacy, and it is bad for the security of our country.

The double ratification is not an appropriate procedure. I have no objection to the development of more and better intelligence systems to monitor these treaties. But negotiations about them could easily be taken into the follow-on negotiations for further limitations, and let us get this treaty, which has been lingering lo too long, actually ratified and into effect.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Colby may be found in the appendix.]

The CHAIRMAN. Thank you very much indeed.

Dr. Panofsky.

STATEMENT OF DR. WOLFGANG K.H. PANOFSKY, CHAIRMAN OF THE COMMITTEE ON INTERNATIONAL SECURITY AND ARMS CONTROL, NATIONAL ACADEMY OF SCIENCE

Dr. PANOFSKY. Thank you very much. I appreciate very much the opportunity to present my views here on these matters. I have testified on this very subject before twice, once on September 12, 1974, and once on September 15, 1977.

I am currently Director Emeritus at the Stanford Linear Accelerator Center and also the Chairman of the Committee on International Security and Arms Control of the National Academy of Sciences. But I want to emphasize that I am testifying as a private citizen.

During my testimony of 1977 I testified that the threshold of 150 KT is much higher than a value which could conceivably be justified as required to assure verification of the occurrence of an explosion. This threshold was clearly chosen to make the treaty acceptable in view of the commitment for testing nuclear explosives which the parties—and I mean both parties—wished to maintain.

During the earlier hearings, I endorsed ratification of the TTBT with the proviso that ratification should in no way lessen the momentum towards reducing further the size and frequency and then eliminating entirely the detonation of nuclear explosives.

I should also like to note that neither the TTBT nor the PNET identifies a valid method through which peaceful and military nuclear explosions can be distinguished. Rather, the PNET serves the purpose of assuring that the individual explosives used for peaceful purposes shall not have yields larger than the limit provided by the TTBT.

In the interest of conserving time I will not repeat these arguments. By virtue of the above history, however, the threshold of 150 KT is somewhat arbitrary. It is indeed paradoxical that, while in my view the 150 KI threshold should primarily be a milestone on the way toward further reductions of nuclear testing, the precision to which this yield can be determined has now been introduced by the Administration to be a matter of major import.

Compliance with a threshold provided in a threshold test ban treaty can never be determined with absolute precision. There are two reasons for this fact: Firstly, any means of measurement, either by national technical means or by more intrusive measures, are by their nature subject to uncertainty.

Second, the weapons designer cannot predict precisely the yield with which the explosive will detonate. Therefore, if a yield threshold—that is, a threshold of energy release—is established, the designer would have to establish a margin of safety by designing his explosive for a lower yield.

All of these uncertainties were recognized during the negotiating history of the TTBT and are incorporated in an exchange of letters between the parties which stipulates that "one or two slight unintended breaches per year would not be considered a violation of the treaty."

Although the treaty has not been ratified, it has been a successful arms control measure within its admittedly limited scope. Before 1976 the Soviets detonated many large explosions in the multi-megaton region. Since March 1976, the Soviets have carried out about 190 underground nuclear tests. Of these, only three or four have involved yields sufficiently near the threshold of 150 KT to be a cause of concern. And there exists—and I would like to emphasize that—no persuasive evidence, either from a seismological or from other sources, which indicates that the Soviets have exceeded that threshold.

Thus I find the assertion by the Administration that the Soviets have likely violated the 150 KT limit to be unsupported by fact, and at any rate the overall compliance record both of the Soviets and the United States with the unratified TTBT has been very satisfactory.

The issue before the Senate is now whether: A, to recommend ratification of the treaty as signed by President Nixon in 1974; or B, as proposed by the Administration, to recommend such ratification with reservations which would require the Administration to negotiate a protocol strengthening the verification provision; or C, alternatively, not to recommend ratification at all.

It is my view that as a matter of policy the treaty process requiring the Senate to recommend to the President ratification by a two-thirds majority should not introduce reservations or require the enactment of additional protocols until or unless there are overriding reasons of national security to do so.

In my view, this is not even remotely the case in this instance, in view of the following facts:

One, there is no persuasive evidence that the Soviets have violated the unratified treaty.

Two, the military importance of the type of variations in yield which might be difficult to observe under the provisions of the TTBT as signed is minor.

Three, the national technical means of verification could be improved significantly unilaterally by the United States. The more invasive verification methods, including the so-called CORRTEX method, which require a more intrusive on-site presence are subject to uncertainties of their own which could only be reduced by means which are likely to prove unacceptable to the Soviet Union and also to the United States.

Let me elaborate on these conclusions. I already cited the compliance record with the unratified treaty as being good. As far as the military importance of yield is concerned, it should be noted that by virtue of tests conducted by the parties prior to the 1976 date specified in the TTBT, both the Soviet Union and the United States have in their stockpiles many types of weapons of yield in excess of 150 KT.

The strategic importance of raw yield of a nuclear weapon is much less than that of other parameters of a strategic delivery system. For instance, if the yield of a weapon were increased by a factor of two, its hard target kill potential would be enhanced by the same amount as if its accuracy were improved by only 26 percent. Similarly, the lethal area of nuclear weapons in anti-population attacks increases only slowly with yield.

Thus, the military importance of small variations above the 150 KT limit is minor. Others here at the table are more qualified than I to testify about the precision of yield assessment that can be made by teleseismic means as provided now in the TTBT. A factor of two uncertainty in yield measurement is the conventionally quoted figure, but it is clear that this number can be significantly improved with appropriate effort.

A missing link is always the lack of detailed knowledge of the seismological characteristics of the test site. The TTBT as signed provided some requirements for exchange of data on the subject, although the significance of such data exchange is limited.

Some attention has been focused on the so-called CORRTEX method, which is a method of yield assessment requiring intimate access to the test location. Here a bore hole roughly 50 feet or so away from the location of the detonation has to be drilled and a cable has to be inserted in such a hole.

Note that United States domestic experience with this method, with the exception of a very small number of shots, is restricted to experiments in which this cable is inserted directly into the primary bore hole through which the explosive also has been inserted and which incorporates the test instrumentation devices; the CORRTEX cable has not been inserted through a separate hole.

The CORRTEX method does not measure yield directly, but rather the speed of the expanding shock wave from the explosion which progressively shorts out the cable as the wave front progresses. Contrary to Administration assertion, the CORRTEX method is also sensitive to knowledge of the geological properties of the materials surrounding the shot, and it is also sensitive to many details such as the location of access shafts and so forth which characterize the test.

Although again these uncertainties could be reduced by highly intrusive methods, some yield uncertainty would remain. The most accurate method of determining yield is radiochemical analysis. This would undoubtedly be considered to be too intrusive and too compromising to Restricted Data affecting nuclear device design to be acceptable to either party.

For all of the above reasons, I strongly conclude that no valid case has been made why the TTBT as signed in 1974 should be modified, and I believe that an extremely bad precedent would be set if the Senate recommended such modification.

Here we have a situation where a rather arbitrary milestone toward further limits in nuclear tests—150 KT in yield—is established in a signed treaty and now, to coin a phrase, the milestone is becoming a stumbling block if excessive and unjustifiable demands are made for the precision with which this yield is supposed to be determined.

It would be an unfortunate precedent indeed if the Senate recommended ratification of the TTBT with reservations relating to verification, considering that there is no overriding national security interest in doing so. It would be a bad precedent in lengthening the already tedious arms control decision process further.

This would further increase the risk that new technology will overtake the rate at which diplomatic progress can be made. If such a reservation were made, the Administration would have to negotiate more intrusive measures of verification, which the Soviets may or may not find acceptable.

Let me therefore summarize my recommendations to this Committee. It would be a most serious negative precedent for future arms control if modification were required of the already negotiated and signed treaty without a valid basis.

I therefore recommend that the Senate transmit the TTBT as signed in 1974 to the President for ratification without reservation. Should such an action not be acceptable, I recommend that no ratification action regarding the TTBT be recommended.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Panofsky may be found in the appendix.]

The CHAIRMAN. Thank you very much, Dr. Panofsky.

Dr. Nordyke.

STATEMENT OF DR. MILO D. NORDYKE, LEADER, TREATY VERIFICATION RESEARCH PROGRAM, LAWRENCE LIVERMORE NATIONAL LABORATORIES

Dr. NORDYKE. Thank you, Mr. Chairman, for the opportunity to address the Committee on this issue of the TTBT and the PNET and their ratification. At the outset, I would like to make it clear that I am speaking as an individual who has grappled with the problems of negotiating and verifying these treaties, such as the TTBT and the PNET, but not as an official representative of the Lawrence Livermore Laboratory.

I would also like to make you aware, for good or for bad, that I was a member of the delegation which spent the better part of some 18 months in Moscow negotiating the rather elaborate verification provisions of the peaceful nuclear explosions treaty.

Verification of any treaty such as the TTBT which involves the measurement or counting of some observable such as yield requires that you deal with uncertainty, something which I am afraid is very hard to deal with at the political level.

This is true regardless of how accurate or how precise the measurement system is. Moreover, the problem is compounded by the fact that there are two types of errors involved: what scientists would call "random" errors and "systematic" errors.

I sometimes try to relate this problem to one of using a scale at home in order to monitor whether you are sticking to a diet or not. The scale reading may vary from day to day because of what you are wearing or how long it has been since you have eaten or whether the scale sticks or some other random factor.

But on the average it will give you the correct value, unless someone has fiddled with the "zero adjust" on the scale, in which case, if they have turned it up a little bit, every time you weigh yourself you will be a little bit too heavy and systematically you will always be over your diet.

Verifying compliance with the TTBT and PNET suffers from the same types of errors, systematic errors and random errors. I would like to say just a little bit about those two types of errors.

The estimation of the yield of a Soviet test is based on measurements of its seismic magnitude as determined by a high quality worldwide seismic network. This magnitude is then used with a magnitude-yield relationship that is based on experience with explosions that we have carried out in which we know the yield and we know the magnitude.

This yield-magnitude relationship is then used to estimate the yield of a Soviet explosion. Evaluation of compliance with the TTBT yield limit will then depend upon the two sources of error, these two that I discussed above:

First, is the yield-magnitude relationship that we are using correct for the Soviet test or is there some systematic difference between our test site and the Soviet test site? Secondly, how should we deal with the random errors that are inherent in any measurement process, inherent in the seismic magnitude determination?

With regard to the first issue of systematic error, the key question is whether or not this magnitude relationship developed for these explosions at the Nevada test site is applicable to explosions at the Soviet test site. Seismic research at Livermore and elsewhere in 1973, well before there was any thought of having a threshold treaty, a yield-based threshold treaty, indicated the existence of significant differences in the character and amplitudes of seismic signals coming out of the Soviet Union.

I do not think this was surprising to the seismologists or geophysicists involved because there are very well known obvious differences in the tectonic structure of the earth beneath the test sites of the two countries.

Over the last ten years, close to some 20 different studies, seismic studies utilizing different techniques, different seismic waves, have been carried out by different investigators to try to quantitatively understand this question.

Virtually all of these studies have shown that the seismic magnitude for an explosion of a given yield at the Soviet test sites will be larger than the seismic magnitude for an explosion at the same yield at the U.S. test site. This offset or difference is what has become known as the bias.

The estimates of bias vary somewhat from one study to another, but on the average they lead to values for the yield estimates for Soviet explosions that are about 40 or 50 percent of the yields obtained from the NTS yield-magnitude relationship.

Because of the effect of this bias correction is to shift the entire body of Soviet yield data to higher or lower values depending on what bias you use, the bias that you choose to use, the value of the bias used for yield estimation, has a major impact on your view of the question of Soviet compliance, because it moves all of the data up or down.

With regard to the second issue, random variations in the seismic data, it can make the estimated yield of any explosion appear to be either higher or lower than it actually was, even if the bias is known. For example, if we were to carry out a series of explosions with actual yields of 150 kilotons, half of them would look like they had yields above 150 and half would look like they were below 150.

That statement is true regardless of how accurate your measurement system is. This is because of random fluctuations. Thus, the occurrence of a yield above 150 kilotons does not necessarily imply by itself a violation. The existence of the random errors in your measurement system means that the issue of compliance must be dealt with in a statistical framework.

Livermore was one of the first to carry out statistical studies of the question of Soviet compliance with the TTBT. Based on the assessments of the best relationship between yields and the seismic magnitudes for the Soviet test sites and the pattern of Soviet testing, it was concluded—we have concluded that the Soviets appear to be observing the yield limit.

The best estimate of that yield limit is consistent with TTBT compliance. However, because of the statistical uncertainty of yield estimates and the uncertainty in extrapolating U.S. experience to the Soviet test sites, you cannot rule out the possibility that a few Soviet tests were above the limit.

It should be obvious from all of the technical factors that I have just discussed that it is impossible to state with 100 percent certainty that the Soviets have or have not violated the TTBT. Because of the statistical nature of the available data, we are forced to deal with probabilities and consistencies.

The critical issue of whether the yields of the possible Soviet violations will give the Soviet Union a militarily significant advantage. I would not be qualified to discuss the military significance of the alleged violations, but based upon my personal assessment of opinions in the nuclear weapons community it does not appear to me that the yield range of possible Soviet violations would open up unique nuclear design opportunities.

Since April 1, 1976, the U.S. and the Soviet Union have agreed to observe the 150 kiloton limitation provided for in the TTBT. However, since the treaty has not been ratified, the two parties have not carried out the exchange of geological and calibration data provided for in the verification protocol.

These data include many things, but most specifically the geological and the geophysical properties of rocks in the testing area and the yield, date, and location for two calibration explosions in each geophysically distinct area.

Similarly, the Peaceful Nuclear Explosions Treaty provides for the exchange of the following information for every PNE, regardless of what its yield is: the purpose, the planned date, the planned yield 90 days ahead of time; a description of the technical features of the project and the geology; as well as after the PNE has been fired, the exact time and the exact yield.

For PNE's with yields greater than 100 kilotons, the protocol provides for onsite verification of geological data; and for groups of PNE's with aggregate yields above 150, the treaty provides for the measurement of the yields by hydrodynamic means, basically the CORRTEX system that you heard described several times over the last couple of days.

Since March 31, 1976, the Soviet Union has carried out over 50 PNE's, scattered throughout the Soviet Union. However, none of the above information for these some 50 events have been made available to the U.S. because this treaty also has not been ratified.

Thus, the United States finds itself in the position that it is observing the 150 kiloton limit, but we cannot reach a consensus whether the Soviets are or not. Some believe that the pattern of Soviet testing is consistent with observance of the yield limit when proper account is taken of the geological differences believed to exist at the Soviet test sites.

Others reject this analysis, and seismology in general, and believe that the Soviets are systematically cheating by a factor as large as two or three.

Failure to ratify these two treaties has denied us a considerable body of data which was designed to improve our ability to estimate Soviet yields. Some have argued that the data to be exchanged would not significantly improve our ability to verify Soviet yields, since there is no way to verify the accuracy of these data.

I think there is some validity to this criticism and I would like to discuss it a little bit. I think everyone would agree that it is impossible to believe the calibration yields that are to be exchanged. They are just numbers written down on a piece of paper and, without some means to verify their numbers for yields—they will be useless. I believe this is a major defect in the present treaty as written.

The geological and geophysical data, however, could prove to be useful. But all things being said, I believe both from a technical and a political viewpoint it would be wise to be able to confirm that geological and geophysical data.

Unfortunately, the major question regarding the differences in coupling and transmission of seismic waves from the Soviet test sites as compared to the Nevada test site does not hinge on the geological or geophysical data that is supposed to be exchanged, but it depends more upon the existence or nonexistence of major differences in the upper mantle deep in the earth, under our respective sites, and on the ability of that upper mantle to absorb seismic signals.

Thus, I believe the TTBT as written contains a number of critical unverifiable provisions and falls short of providing the verification capability conceived of by those who negotiated it. In my view, the first step to enhance the verifiability of the TTBT would be to consider measures that would rectify these obvious defects.

The most straightforward approach in my opinion would be to verify the yields of the calibration explosions that are provided for in the protocol with onsite hydrodynamic yield measurements. The procedures spelled out in the PNET protocol, with some minor modification, could well be satisfactory for carrying out these measurements.

This could possibly be implemented by carrying out so-called PNE's at the test site whose peaceful purpose would be to serve as seismic calibration explosions. Observing the drilling and the logging of the emplacement holes for these events, as provided for in the PNET, would serve to provide calibration confirmation of the geological data exchange package in the vicinity of these calibration explosions.

Such an approach would not significantly reduce the random uncertainties associated with the estimates of yield at the Soviet test sites. But, perhaps more important, having verified yield data from the Soviet test sites would determine the validity of the seismic methodology and thus resolve the present major disagreement regarding the existence or non-existence of a systematic error or bias between the United States and the Soviet test sites.

[In response to a request from Senator Pell, Dr. Nordyke subsequently provided the following additional statement regarding the suggested approach:]

ADDITIONAL STATEMENT BY DR. MILO NORDYKE

The implementation of an agreement, based on the terms of the PNET Protocol to confirm, with on-site measurements, the hydrodynamic yield of the "two tests for calibration purposes from each geophysically distinct testing area" of the test sites called for in the TTBT Protocol, would have the following beneficial impact:

(1) It would provide yield estimates for these explosions with an uncertainty much smaller than that currently attainable with seismic means. These hydrodynamic yield estimates would be used to determine the existence or non-existence and approximate value of the bias believed to exist between the U.S. and Soviet test sites. They would hence confirm the validity of the seismic methodology for determining Soviet yields and eliminate the most serious disagreement regarding Soviet yields. They would not, however, significantly reduce the overall randon uncertainty of seismic yield estimates. Random uncertainty can be adequately treated with stand-

ard statistical procedures. The random uncertainty of seismic estimates can also be significantly reduced by the development of seismic yields based on independent seismic waves.

(2) Such an agreement would also provide a signficant on-site presence at the test sites, including an opportunity for confirming geological and geophysical data in the vicinity of the calibration explosion.

(3) Such an agreement would, for the first time, capture in international law the extensive on-site verification provisions of the PNET, as well as assure that many of them, i.e., those relating to hydrodynamic yields, would in fact be implemented.

Dr. NORDYKE. This first step would appear to me to be the minimal enhancement that should be taken to rectify the obvious inconsistencies of the TTBT as written. Further steps could be considered that would primarily have the effect of reducing the random errors, not the systematic but the random errors, that would be associated with the yield estimates.

One approach would be the development of methods for use of other seismic waves which would be independent of the one seismic wave presently used. This approach would require no supplemental treaty provisions beyond those needed to implement the first step outlined above for monitoring a 150 kiloton threshold. It would require a continued program of seismic research focused on the issue of developing these new methodologies.

An alternative approach to significantly reduce the random uncertainties would be the on-site measurement with CORRTEX of all weapons tests above 75 kilotons, about which you have heard a good bit in the last couple of days.

The CHAIRMAN. Thank you very much indeed. Are you through?

Dr. NORDYKE. I have just a half a page left, if I may continue. I think the question of whether to proceed with the ratification of the TTBT and the PNET is at the heart a political judgment, requiring the balancing of a number of issues.

The key issue is the extent of the possible Soviet evasion of the treaty threshold within the statistical uncertainties, whether that would threaten the U.S. national security. Inherent in this judgment is the quantitative element of how uncertain our measurement system is or the uncertainty of any verification system, and that has to be balanced against a qualitative judgment on what risk of detection of an evasion attempt the Soviet Union would be willing to accept.

My own judgment is that the United States should proceed with ratification, but only if, as a minimum step, the U.S. can reach agreement with the Soviet Union for on-site hydrodynamic verification of the calibration yields and on-site confirmation of the geological data called for in the TTBT protocol.

Ratification of the TTBT with such a supplemental verification agreement would eliminate the most serious concern regarding Soviet cheating and bring into implementation a treaty that provides for a substantial exchange of data and on-site verification activities on the soil of both countries.

Thank you.

[The prepared statement of Dr. Nordyke may be found in the appendix.]

The CHAIRMAN. Thank you very much, Dr. Nordyke.

Professor Richards.

STATEMENT OF PROF. PAUL G. RICHARDS, LAMONT-DOHERTY GEOLOGICAL LABORATORY, COLUMBIA UNIVERSITY

Dr. Richards. Mr. Chairman, members of the Committee:

I was asked last week to testify to you on the state of the art in seismology with reference to monitoring explosions. I have taught at Columbia for 15 years and am co-author of a two-volume textbook, "Quantitative Seismology," that has recently been translated into Russian and Chinese.

Perhaps I am here, too, because in 1984 I began a 12-month appointment as a visiting scholar in the U.S. Arms Control and Disarmament Agency under a program, sir, that you initiated.

The Chairman. Thank you.

Dr. Richards. I would like to just cover the main points of my written testimony and request that the balance be placed in the record.

The Chairman. The full text of your statement will be inserted in the record as if read.

Dr. Richards. Thank you.

In the case of seismic monitoring, much of the relevant technical details are quite routine and openly known. Of course, I do not have time to cover them in a lecture format in this statement, and it would not be appropriate. But again, I would appreciate being able to insert for the record a short paper entitled "Seismic Monitoring of Nuclear Explosions." It is from an article I finished last month.

The Chairman. Without objection, it will be included.

[The material referred to appears in the appendix.]

Dr. Richards. This paper may serve as a short primer on the relevant technical details.

At present, for explosions of concern with respect to the 150 kiloton threshold, a factor of two is commonly quoted. By this is meant that the seismic yield estimate, when multiplied and divided by two, gives a range of yields within which one has confidence that the actual yield really does lie.

This level of confidence can itself be expressed as a percentage, and the usual convention in seismology is the ninety-fifth percentile. Some figures are shown on the second and third pages of the written version of my testimony, pages that I think give the mental images that a scientist uses in characterizing uncertainty.

However, I want to emphasize that a value of two for the factor of uncertainty is not a fair summary of current capabilities, because it refers only to one type of seismic method, and for large explosions there are typically three or more independent seismic waves upon which separate seismic yield estimates can be based.

If the average of these estimates is taken as the central value, with a factor of uncertainty of two for each of the three methods, it is easy to show that the resulting seismic yield estimate has only a factor of 1.5 uncertainty. Now, there may be debate as to whether the available seismic methods are each equally good and how they should be weighted in coming up with the best estimate using more than one seismic method.

My point is simply that for large explosions, which generate a variety of different seismic waves, the factor of uncertainty is less than two.

Now, concerning interpretation of yields for the largest Soviet explosions, I recognize that the question of Soviet compliance has to be decided as a political judgment. The way that the technical community can contribute is to give a best professional opinion on the relevant numbers.

For example, we come up with the best estimates for the yield and then we have to describe our uncertainties associated with these estimates. The biggest Soviet explosions in recent years have been in eastern Kazakh near the town of Semipalatinsk. There have been many open literature studies of these events, and typically these papers do show some explosions with yield estimates above 150.

But there are a couple of ways to see that this is not the end of the story. For example, consider a program of testing at 149 kilotons once a year. This is just a thought experiment. Then because each seismic estimate is not going to be absolutely accurate, some of those seismic estimates will come in above 150. In fact, this would be expected to happen if the Soviets were repeatedly testing right up to the allowed threshold.

Another way to appreciate that a few events with seismic yields above 150 does not directly indicate non-compliance is to consider what would happen if the seismic method were applied to our own test site in Nevada. This basic idea, I may say, is described in the recent Congressional Research Service document that is cited on the first figure in my written testimony.

Because of the uncertainties, some of the U.S. weapons tests would be estimated from seismic measurements to be over 150 kilotons. Now, fundamentally I want to note that this problem of assessing compliance with the yield threshold will always have this kind of difficulty.

It is a problem that is not unique to seismology, nor to 150 kilotons. In fact, if there were a method that had a 1.1 factor of uncertainty, that is to say an excellent yield estimation method, but if testing was routinely taken up to the threshold but not above, then there would still be a nearly 50-50 probability that the central value estimate would exceed that threshold for the largest events.

It is a slight change of subject, but I think still somewhat related to note that part of the written record concerning this treaty, in fact the negotiating record, contains some important language concerning slight unintended breaches that is part of the formal record on this treaty.

And I have put in three paragraphs concerning those mistakes, what is called a mistakes understanding, into my written testimony.

I also note that President Reagan's letter of October 10, 1986, to Senator Goldwater contains the following words:

> How one transitions to a total test ban regime is no less critical a concern than verification or any other national security issue related to an eventual implementation of a CTB.

In this connection, I was asked a few months ago by another Committee of the Congress to suggest how monitoring issues might enter into the planning of a completely new test ban treaty. This question was a stimulus to co-author a paper on the subject, and again I would appreciate a short paper being placed in the record of this hearing.

The **Chairman**. Without objection.

[The material referred to appears in the appendix.]

Dr. **Richards**. Thank you, sir. It is entitled "Toward a new test ban regime," and it is an attempt to develop a practical compromise between prompt negotiation of a comprehensive test ban and the status quo. It describes several technical matters that are relevant to the present debate on the 150 kiloton treaties.

Although I was asked to characterize the state of the art in seismology, I think it may be more important to convey the sense of consensus for that part of the work that is more seasoned. Thus, I have not covered the latest research ideas because they change all the time, which I know from experience can be maddening to policymakers who try to follow them.

But these new ideas do exist and they are likely to result in new, slightly different, and presumably better seismic yield estimates. However, at this stage of the debate on the threshold treaties, it is the methods that have been around a while that matter the most, and I think that there appears to be a consensus on the qualities of these seismic methods.

Perhaps one way to see this is that the seismological techniques most relevant to monitoring threshold test ban compliance have not been presented to the Congress in the last two years as an area characterized by disagreement between experts on technical issues. If there were no consensus, it should not be too difficult to put a few of us seismologists side by side and thus make it visible that consensus is absent.

Of course, there have been spokesmen who are not seismologists who say that seismic yields can be off by a factor of two. But I hope I have indicated that this is an unfair characterization of what it is that the technical community is actually saying.

I will conclude simply by noting that seismology is a much larger subject than is generally recognized. It has been funded at the roughly 10 to $100 million a year level by several federal agencies, about ten of them. It is supported significantly by several individual states of the Union and by several utility companies. It is associated with huge expenditures, on the order of billions of dollars in recent years, by U.S. oil companies to acquire and process geophysical data. And I would say too that about 50 U.S. universities offer graduate degrees in seismology or related areas of geophysics.

Within this large profession, I say there is consensus on the main issues related to the factor of uncertainty. It is less than a factor of two.

Finally, sir, when it comes to some of the material that needs to be presented in closed hearings, I would ask if it might be possible that I might make a contribution, a written contribution there.

The **Chairman**. What was your question, again?

Dr. **Richards**. If I might make a contribution, a short written contribution to the written closed record.

The **Chairman**. Absolutely, without objection.

Dr. **Richards**. I have concluded my statement.

[The prepared statement of Dr. Richards may be found in the appendix.]

The **Chairman**. Thank you very much. Thank you very much indeed, gentlemen.

We will start out with a ten minute rule and I will limit myself to that to start out with.

Mr. Colby, as I understood it you believe that the two treaties are really effectively verifiable as negotiated in 1974 and 1976?

Mr. **Colby**. Yes, sir.

The **Chairman**. What is your own view of how important you believe it is to monitor Soviet compliance with on-site inspection? Do you feel that that would improve things?

Mr. **Colby**. It would certainly assist. It would certainly very substantially assist.

The fact that the Soviets have invited a team over there is an indication that they are moving in that direction. They have said in several different surroundings that they are prepared to move into on-site inspections. Now the question is how many, where, how do they act.

That required a great deal of negotiation in Geneva on the peaceful uses treaty, and of course it was the basis of failure in the comprehensive test ban treaty in 1963.

The **Chairman**. From your familiarity with intelligence methods, it would be obvious, I would think, that on-site inspection would mean that the people who go there keep their eyes open for anything else they see. Would that be more to our disadvantage or to the Soviet disadvantage?

Mr. **Colby**. It would be more to our advantage. They view it as to their disadvantage. I think they are mistaken, but they certainly view it. They are very suspicious of people looking into their private affairs.

The **Chairman**. I was interested in Dr. Nordyke's proposal. Were you listening to that and do you have any comment on it?

Mr. **Colby**. Yes. Well, I think that the idea of improvements certainly is a valid subject to take up with the Soviets. But I would not hang the whole treaty on it.

In fact, he states that we would have to accept their data. I suspect that we have ways of cross-checking it, not confirming it directly. We are following these explosions today without that data. This would be additional data.

There is very little indication of a motive they would have for misleading us in that data, because sooner or later we are going to find it out and find out that they were telling us the wrong answer.

The **Chairman**. Thank you. Thank you very much indeed, Mr. Colby.

Dr. Panofsky, what kind of verification capabilities do you believe we should be working on to be prepared for further testing? In other words, in what direction should we be going in our scientific research?

Dr. **Panofsky**. First we will have to distinguish verification capabilities which relate to defining a threshold, namely which quantitatively measure yield, and those which improve identification and detection, which is the direction we want to go to in order to prepare for lowering the threshold eventually to zero.

I think those are quite different problems. Dr. Nordyke has indicated quite clearly that a threshold introduces uncertainties of its own. My personal view is the same as that of Mr. Colby, that the present treaty is adequately verifiable and that the question of doing further research and development and also implementation of verification methods is an independent matter which could be associated with further efforts on reducing the frequency and yield of nuclear tests.

I think we should, for instance, work further on the kinds of things which Dr. Richards talked about, namely using the combinatorics of the various types of seismic signals. We should learn more about the on-site emplacement of devices for hydrodynamic tests, because there are still many uncertain factors concerning them.

But I believe we should recognize that the matter of ratification of a treaty which was signed as being in the national interest of both parties should not be held hostage to progress of research in these different directions.

The CHAIRMAN. Thank you very much, Dr. Panofsky.

Just following up that thought about seismology, Professor Richards, is it your view that seismology research will move along in such a way that it will be as accurate as CORRTEX will be?

Dr. RICHARDS. For explosions specifically of importance, at this roughly 150 kiloton threshold, I would say no. I think that fundamentally the CORRTEX method is likely to be slightly better than seismology will be.

However, there are many other situations, notably for rather smaller explosions, down below 150 kilotons, where I think the situation is completely the other way around.

The CHAIRMAN. Dr. Panofsky?

Dr. PANOFSKY. I would make one comment on that. In these questions, the presumption is always made that the CORRTEX method is something which is absolute and which can be made available off the shelf, so to speak.

Actually, the CORRTEX method is itself sensitive to many parameters which are associated with the way the test is being conducted. And the question to what extent that can or would be made available would determine what the required accuracy is.

So although I agree in general terms with what was just said, one should not create the presumption that CORRTEX is something which you just plug in.

The CHAIRMAN. Thank you.

Dr. Nordyke, what is your own assessment of the value in verifying the Soviet compliance? Do you think that we should move further down this road, or would you enlarge a bit on that?

Dr. NORDYKE. Well, I think that the present record is consistent with Soviet compliance. But I think if you are going to move to ratification or move to capturing these treaties in international law, it seems to me that we really should take advantage of the provisions that are there and make them valid provisions.

I think as I indicated, simply handing over yields is an unacceptable procedure from the standpoint of the fact that there is just no way on earth that one could defend using those numbers in your evaluation of Soviet tests. Therefore, they are useless to your estimation capability.

I think they could play a significant role, if you knew those yields with the accuracies that CORRTEX would give you. With a high degree of accuracy, then I think you could at least eliminate the most egregious disagreement that exists, and that is whether or not seismology is all wet or whether seismology is a reasonable way to try estimate these yields.

The CHAIRMAN. Thank you.

Mr. COLBY. May I speak to that for a moment, Mr. Chairman?

The CHAIRMAN. Yes.

Mr. COLBY. I certainly accept the statement as said. But you get back to, are the Soviets apt to give us totally false data and we never discover it? We had this same question in the exchange of weapons lists on the signing of SALT II, when the Soviets had to give us a list of their weapons.

Now, we had independent ways of determining it. It so happened that the figures came out roughly the same, practically the same, with some minor changes. If they had given us a false figure and we had known it, even later on, that it was then false, it affects the entire treaty relationship and all the benefits that come to the Soviets from the treaty.

I think that that must be factored into the estimate. It is not proper just to assume that they will give us the false data, of such data which can be confirmed.

You also have the problem of discipline in the Soviet Union, that if they consciously give us false data like that you are going to have individual defectors on your hands who are going to tell us about it. That has happened in the past as well.

The CHAIRMAN. Thank you very much, gentlemen. I will turn now to Senator Sarbanes.

Senator SARBANES. Thank you, Mr. Chairman.

Dr. Nordyke, do you think the current regime is better than no regime at all?

Dr. NORDYKE. Well, the current regime is one that is based entirely on national technical means, and so in a sense is nothing at all beyond what we can do without any cooperation from the Soviets.

Senator SARBANES. Do you think we would be better off if we could just get these treaties out of the picture and each side could test it at whatever level it wanted without any concern about complying with a treaty, although it is not yet in force under the requirements of international law?

Do you think it would be better, in other words, to go back to where things were before these treaties were ever reached?

Dr. NORDYKE. Well, I think it is clear that the U.S. would be at a disadvantage if there were no treaty, if there were not the 150 kiloton limit because the Soviets have the capability to test at much higher yields than we do within the resources of their country.

Senator SARBANES. Let me be very certain that I understand that. Given that, it is your view then that this regime limiting the yields to which testing can be carried out is to our advantage, that we benefit by having such limitations in place? Is that correct?

Dr. NORDYKE. I think we have an advantage in having a 150 kiloton limitation in place as opposed to no limitation, yes.

Senator SARBANES. As opposed to no limitation?

Dr. NORDYKE. That's correct.

Senator SARBANES. Of course, you would like to get even more verification into it if you can. That may or may not be possible. But in any event as between not having any regime of limitation and having the existing one you prefer to have the existing one?

Dr. NORDYKE. Well, we are operating under the limitations of the existing one. I see no prospect really of abrogating it, because, as I say, it would be to our disadvantage to abrogate it, so it seems to me it would be wise for us to take advantage of what is in the treaty if we are going to continue to observe it. I believe that it would be possible and it would certainly be wise, to try to negotiate a fairly straightforward verification of the calibration yields.

Senator SARBANES. Would it have been your assumption that if we were going to try to achieve that, a reservation to the treaty to obtain further verification would have been submitted to the Senate at the time we were asked to ratify them? Would that have been your assumption as to how to proceed?

Dr. NORDYKE. Well, I guess I really do not feel qualified to comment on what would be the most appropriate procedural way in which to deal with this issue.

Senator SARBANES. Let me ask Mr. Colby about that.

Mr. COLBY. I think if the then administration had had substantial qualms about the verifiability it would not have signed the treaty because the treaty has in it the assumption that it is verifiable. No administration could send a treaty up to the Senate unless it thought it was verifiable because that is the first question that comes up.

Senator SARBANES. But if this administration takes the view that they are not satisfied with the verification, and of course you differ with that—it is your view that these treaties as submitted are verifiable—but assuming they take that view, would you not expect them to submit to us the substantive verification change in the treaty that they thought was necessary in order to justify ratification?

Mr. COLBY. I think that constitutionally what they would do is go back to the Soviets and renegotiate some element of the treaty and then submit the revised treaty to the Senate for ratification. You do have a new administration and a new administration may disagree with a signed agreement from the previous one. The President disagrees with SALT II and has announced that we are not going to abide by it. That is his privilege. He can do that. I think he makes a mistake, but that is his privilege. But he does not seek ratification of it.

Senator SARBANES. Let me just read to the panel, because I am anxious to get your reaction to it, the terms on which the President has written to us in terms of the Senate proceeding to give its advice and consent to these treaties. He says, "The Senate's resolution of advice and consent to ratification is subject to the condition that the President shall not proceed with ratification," and then he names the two treaties," until the President has certified to the Senate that the Union of Soviet Socialist Republics has concluded with the United States additional agreements expanding upon the obligations stated in Article II of the Treaty on Limitation of Underground Weapons Tests, including provisions for direct, accurate yield measurements taken at the site of all appropriate nuclear detonations, so that the limitations and obligations of these treaties, *inter alia* the 150 kiloton limit, are effectively verifiable, and until such agreements have been submitted to the Senate and the Senate has advised and consented to their ratification."

Now, my perception of this is that we are being asked to do an empty act, and perhaps it is even worse than an empty act, as I will detail in a minute. The President in effect has said to the Senate, advise and consent to these treaties but condition them so that that advise and consent means nothing until subsequently you advise and consent to a further agreement addressing verification.

It would seem to me the orderly way to proceed on the President's part, if that is how he feels, is not to seek the advice and consent to the treaties until he can submit the verification provisions that he thinks are necessary in order to warrant advising and consenting to them. Otherwise, this is in a sense almost a charade.

It may be worse than that, because it then would mean that the treaties could no longer be approved as submitted, if one chose to do that based on a judgment of our national interest. Once advice and consent was given to them with conditions, at least as I understand the law, the treaties would be off the calendar to be approved as submitted. They could only then be put into effect if a subsequent agreement was reached and finally ratified, which leads me back to the question I put to Mr. Nordyke, and that is: Do we then run the risk of abandoning this regime altogether and having none of the restraint that comes with it? Some argue that this regime is faulty. Others argue that it is adequate. But in any event in either instance I gather no one at the panel disagrees with the response that the current regime limiting it, whether adequate or inadequate, is preferable to no regime at all.

Does any member of the panel disagree with that?

Dr. **Panofsky**. No, sir.

[Mr. Colby nods negatively.]

[Dr. Nordyke nods negatively.]

Dr. **Richards**. I am sorry, I have to interject that I am not sure that I clearly understand that. When you say no regime at all, do you mean simply no restraint on testing up to megatons?

Senator **Sarbanes**. Yes.

Dr. **Richards**. Oh, yes, I think that would be terrible.

Senator **Sarbanes**. I mean back to the situation before we ever had the treaties.

Dr. **Richards**. Yes.

Senator **Sarbanes**. I think some people have lost sight of the fact that the treaties have brought very real benefits to the United States, did they not? I mean, memories have failed. Now everyone is arguing about whether the test at is 150 or 200 kilotons. There was a time before these treaties ever came in when we were confronting megatonnage in terms of testing, were we not? What were the implications of testing at that yield? Who wants to take a crack at that? Dr. Panofsky?

Dr. PANOFSKY. Well, prior to the enactment date of the TTBT, which was 1976, there were a number of considerable shots in the three to five megaton range and prior to that there were some shots even much larger than that, and there is no question that if you look at the frequency distribution of yield versus time, there has been an abrupt drop from the large shots to the 150 KT limit, and if you look at such a plot, the small variations about which people are now debating are hardly visible to the naked eye.

So in my view this whole question whether a factor of two or a factor of 1.3 or 1.5 can be attained by seismic detection is to some extent irrelevant relative to the overall security benefit of the treaty to the nation, and therefore I would like to reemphasize that there isn't such a thing as, to quote your quotation from the President saying there is a" direct, accurate, yield measurements". There is no such thing because of just the remarks which were made about the necessary uncertainty of any measurement.

So therefore I believe that this whole debate about improving verification is one which has some merit on its own but should not in any way be linked to the verification, to the ratification process by the Senate at all.

Senator SARBANES. May I just ask Mr. Colby to respond?

Mr. COLBY. If I might add a word, I would call it bad diplomacy as well as bad constitutionally and bad for our security. We had an experience with a new administration attempting to change what had been signed up with the Soviets by your witness yesterday, Former Secretary Vance, who went over to the Soviets in 1977 with a proposal for a major change in the SALT arrangements that had been negotiated at Vladivostok and which were practically wrapped up as far as the Soviets were concerned. The Soviets almost threw him out of the Kremlin.

We then went back, regrouped, and eventually achieved the SALT II agreements, which essentially encapsulated the general outline of the agreements made in Vladivostok in 1974. Now, if you then go back and say, no, we are not going to sign this treaty, and not going to ratify this treaty until we get it all fixed up with our great technological fix, I do not know what the Soviet reaction is going to be. But I say that we have had one experience with that, and it was bad.

Senator SARBANES. Accepting that point, let me just ask one further question, and I see my time is up. What reason do you think there is for taking this approach which, as best I have been able to learn so far, is totally unprecedented, of asking the Senate to advise and consent to two treaties, but then attaching a condition to that advice and consent that in effect renders it null and void until a subsequent agreement is reached which the Senate would then advise and consent to?

Mr. COLBY. I think the administration wants to have its cake and eat it. It wants the benefits of the present regime, but it wants these technological fixes and improvements in verification. It assumes that the Soviets will not back off from the present regime. I think that is a very generous assumption.

Dr. RICHARDS. I would like to respond to the Senator, concerning the idea that possibly a clear statement of what effective verification means should be given prior to this process, as part of the current process of advice and consent. I would simply say that if it were clearer to the technical community as well what is meant by effective verification, frankly, that would be helpful to the technical community as well.

I would say that in 1974, when the more important, I think, of these two treaties was signed it was clear at the time what seismic uncertainties were, and in the last 12 years those uncertainties have not gotten worse. The seismic method has got better. So clearly what has happened in the last 12 years is that the standard of effective verification has changed. I guess I have no quarrel with that either. That is our elected leadership's prerogative to do that.

But I do say from the technical community standpoint that there is that need to know what is effective verification, what kind of experiments should be planned, how should one try to improve things.

The CHAIRMAN. Thank you very much.

Senator Simon.

Senator SIMON. Mr. Colby, the previous panel said that if we go ahead with this as is, we reduce the certainty that our nuclear warheads will work, and one of the witnesses in his written testimony specifically faulted the comprehensive test ban for saying that would cause real problems. You in your written testimony testified for it. I guess there are two questions. One is, will there be any reduction in certainty, and Number Two, if there is a reduction in certainty, does that discourage first strike ability? Does it stabilize the situation or does it destabilize the situation?

Mr. COLBY. I would defer to the technical experts on whether there is a degrading of certainty. I would have to assume that there would be some if you would just look at the thing from the outside. The question is whether that reduction in certainty is worth the benefits that you receive from a comprehensive test ban which I think would be very substantial, and as close as we can get to one, and we do not have to go there all in one jump. You can move down to it in degrees.

If you had uncertainty of your weaponry, yes, you would be less inclined to engage in a first strike, but frankly, I think the first strike scenario is pure fiction anyway. There is only one absolute certainty in this whole field, and that is that if either country uses nuclear weapons against the other the retaliation is absolute. And it is devastating. And that is a certainty, and that is where we have been for the last 20, 30 years, and that is where we still are.

Senator SIMON. Dr. Richards has two sentences that I think are worth repeating for the record again. He says.

> The value of two for the factor of uncertainty is not a fair summary of current capabilities because it refers only to one type of seismic method. For large explosions there are typically three or more independent seismic waves upon which separate seismic yield estimates can be based. If the average of these estimates is taken as a central value yield with a factor of uncertainty of two at the 95 percent level for each of three methods it is easy to show that the resulting seismic yield estimate has only a factor of 1.5 uncertainty.

Dr. Richards, may I ask you this question? On research on seismology, what are we doing? Are we doing enough? Are we moving ahead so that we are going to narrow this thing even further?

Dr. **Richards**. Well, sir, I think there is a vigorous research program in seismology generally directed in this area of monitoring explosions. It is certainly the case. In the short written statement that I would wish to make for the closed record I would comment further on those programs. I will say that research in seismology generally in this country has benefitted hugely over the last 20 years from this national need that we have to understand how to monitor explosions, but currently most U.S. seismologists are not working in this area. Mostly they are working on earthquake prediction, understanding earth structure in a variety of different ways.

I would like to think—I am sure it would happen—that if it became a national plan, say, to move to a new testing regime, a new test ban regime, then in fact many seismologists would come swinging right back into the other set of technical issues which are related not to the threshold treaty but the separate technical issues related to monitoring at much lower yields.

Senator **Simon**. Dr. Nordyke has one sentence that I would also like to read here. "Failure to ratify these two treaties has denied us a considerable body of data which was designed to improve our ability to estimate Soviet yields." And then one very brief question to Dr. Nordyke.

You talk about the hydrodynamic yield measurement. Is that the same thing as CORRTEX?

Dr. **Nordyke**. Yes, and the answer to your latter question is yes. Hydrodynamic yield, that is, CORRTEX is a particular instrument that is used for hydrodynamic yield. At the time the Peaceful Nuclear Explosion Treaty was negotiated it was called SLIFER, a different kind of instrument, and they measure the same thing.

Senator **Simon**. Dr. Panofsky, do you disagree?

Dr. **Panofsky**. It is one of several methods. CORRTEX is one of several methods for determining hydrodynamic yield.

Senator **Simon**. OK. I have no further questions. Thank you.

Dr. **Nordyke**. Excuse me. I would like to comment about the one line you quoted?

Senator **Simon**. Yes.

Dr. **Nordyke**. I am trying to remember the line again.

Senator **Simon**. Failure to ratify these two treaties has denied us a considerable body of data which was designed to improve our ability to estimate Soviet yields.

Dr. **Nordyke**. I wanted to point out that I believe that as constructed the treaty doesn't allow us to verify that data. That may have been the plan which assumed that we would be able to know the yields, but I think to really implement the data to make that data which is supposed to be transferred truly useful within the U.S. intelligence process you need some way to believe it, and I think verification of that information at some level is highly desirable.

Senator **Simon**. I thank you.

Thank you, Mr. Chairman.

The **Chairman**. Thank you.

Senator Moynihan.

Senator **Moynihan**. Thank you, Mr. Chairman.

This is the first occasion that I have had the honor to ask questions as a member of this panel. You have been kind enough to invite me on other occasions. I hope I will not seem too abstract, but I do have a question I would like to put to the distinguished and luminous set of witnesses; a question that goes to a problem one always runs into when you have persons in the political world dealing with issues in the world of science.

Let me ask Dr. Panofsky, who is such an eminent person. I would not be wrong if I associated the onset of nuclear physics as a serious subject with, say, 1920?

Dr. PANOFSKY. Yes, about that.

Senator MOYNIHAN. About 1920. Well, the development of statistical probability is only about a generation earlier.

Dr. PANOFSKY. That is correct.

Senator MOYNIHAN. Probability is as new a field as nuclear physics by approximately 20 or 30 years, and we associate probability with names the way we associate phsyics with names. There are specific men at times who did specific work.

In your experience how many of the political and diplomatic people who negotiate our treaties have a real sense of what nuclear fission is?

Dr. PANOFSKY. I think the people who have been involved in this——

Senator MOYNIHAN. I am talking about within in this committee, perhaps. [Laughter.]

Dr. PANOFSKY. I would like to disqualify myself on that question. [Laughter.]

People who have been involved with nuclear arms, I believe the majority, the vast majority, have recognized that the advent of nuclear energy has made it possible to package about a million times more energy in any weapon. As a consequence of that the whole strategic equation is changed.

Senator MOYNIHAN. That is just an English sentence; but who could diagram the fission process, who could do the equations? Nobody.

Dr. PANOFSKY. Few.

Senator MOYNIHAN. None of the people who are actually required to negotiate our treaties. We all accept that we have a very limited understanding of fission. How general do you think the understanding of probability is?

Dr. PANOFSKY. It is a little bit larger because probability and statistics also plays a large role in many aspects of business and economic forecasting and so forth.

Senator MOYNIHAN. How many Senators do you think are skilled in this?

Dr. PANOFSKY. I do not know, but I believe the very fact that the President's letter requesting ratification includes the term that there should be direct, accurate yield measurements certifies to the fact that you are being asked to do something which is not meaningful.

Senator MOYNIHAN. Which you cannot do. Yes, sir, that is a meaningless statement. There is no such thing.

Dr. PANOFSKY. That is right. The question is, you have to judge whether the standards of verification which were judged adequate by President Nixon in 1974 are being judged adequate today and standards by definition require a judgment of whether the necessary uncertainties in verification are acceptable in view of the national security advantages of the treaty.

Senator MOYNIHAN. Mr. Chairman, the point I would like to make is simply that an easy understanding of what a 95 percent level of confidence means is not normally to be encountered among speech writers and people who draft letters that are sent to be signed. If you can verify within 95 percent, that constitutes verification. That is what verification means. On this topic we can say verfication is possible with a range of confidence of two or 1.6 or what you will, but if you set out at a level of 1.5, to verify a limit of 150 kt., 95 percent of the time you will get something between 75 and 300. That is in fact what verification means, not that you will always get 150. And the number of events involved is very small. I believe Dr. Nordyke, said that, for example, if we were to carry out a series of explosions with actual yields of 150 kilotons on the average half of them will have estimated yields greater than 150 and half smaller, regardless of how accurate the measurement system is. I think you have to qualify that and say this would be the case if you carried out an almost infinite series.

Dr. NORDYKE. Oh, yes.

Senator MOYNIHAN. Every one of them could be on the low side or every one of them could be on the high side and you still would be within the statistical probabilities. It is like flipping a penny. You can flip a penny and have it come up heads a million times and the odds of it coming up heads the next time are 50-50.

Dr. NORDYKE. I would agree with you until you went to infinity or a large number. It is possible, yes.

Senator MOYNIHAN. Yes. What I want to suggest is that it is possible this Committee is being misused, Mr. Chairman, by persons who either do not know what the probabilities are in verification or think we do not know. I think we do know. I think we have heard what the range is, and it is a rather limited range. You go from about 75 to 300 if you set out to be 150. I would like to hear more about the bias that Dr. Nordyke spoke of. I do not want to speak much longer, but I would just ask you this question.

Knowing these probabilities, if you really started out to cheat, you would take the risk of being out on the far tail of explosion levels. That would really show up fast. If you set out to do a 300 KT you could show up on our seismograph as 450, correct?

Dr. NORDYKE. Well, yes. I think sometimes the possibility of a 150 KT explosion looking as large as 200 or 250 KT is used to say, well, then, somebody could go to twice that yield and shoot 300 or 350 kilotons and still have it look like it was only 200 too. The problem is, if you fired an explosion at 300 or 350——

Senator MOYNIHAN. It could very well appear to be 450.

Dr. NORDYKE [continuing]. It could very well appear to be 450 or 500 and the evader has to take that into consideration in his judgment.

Senator MOYNIHAN. It seems to me, Mr. Chairman, that we ought to tell the White House that we know what verification means. It is a range of probable measurements, any one of which could be accurate within that range, and it, too, is high. I think Dr.

Richards has suggested that 1.6 is more likely. That is a pretty tight range, isn't it?

Dr. PANOFSKY. Yes, sir.

Dr. RICHARDS. Yes.

Senator MOYNIHAN. If you have measured atoms roaring down your accelerator—if you get things within a probability of two you are pretty happy, are you not, Dr. Panofsky?

Dr. PANOFSKY. It depends on what we are looking for.

Dr. RICHARDS. To give you some relevant numbers, a factor of two would indeed be that range from 75 to 300 kilotons. And if one believes that the factor of two is the right characterization of uncertainties, then one would say there is a 95 percent chance of events tested actually at 150 being in that range from 75 to 300.

The thrust of part of my testimony was that I believe a factor of two uncertainty is not a fair characterization of seismic capability, but the number would be I think closer to 1.5. In fact, at 1.5 the range would be from 100 to 225. It is narrowed.

Senator MOYNIHAN. Well, that suggests that this particular form of measurement has advanced to a very considerable degree.

Dr. RICHARDS. Yes.

Dr. PANOFSKY. I believe the issue here is one of military importance. I mean, we are talking here about various factors. We keep ignoring the fact that the military importance of yield as such has drastically decreased during recent time?

And as the two laboratory directors have testified here, we have unilaterally been able to decrease the yield of our weapons because of the fact that other parameters, such as accuracy, fractionation, and so forth, have taken its place. So therefore I find it quite astonishing that the matter of detailed precision within which this threshold can be measured is being introduced as a possible obstacle toward ratifying this treaty.

The yields themselves are not of great military importance.

Senator MOYNIHAN. If I may make one final statement, the precision with respect to this matter involves a range of probabilities?

Dr. PANOFSKY. That is right.

Dr. NORDYKE. I guess I would like to add at the end here that what you are discussing is the random probabilities.

Senator MOYNIHAN. And a bias.

Dr. NORDYKE. It is my belief that the random probabilities can be dealt with on a statistical basis. I think the procedures are there, the words are there. It is difficult to make judgments on a political level what these words mean, but I think it can be handled.

The problem which is really the most difficult problem to deal with is this problem of the systematic error, because there is no direct data that we have from the Soviet test site. And in the absence of that direct data, there are always arguments as to why it could be different.

Senator MOYNIHAN. Thank you.

The CHAIRMAN. SENATOR SARBANES.

Senator SARBANES. No further questions.

The CHAIRMAN. Senator Moynihan, further questions?

Senator MOYNIHAN. No, thank you, Mr. Chairman. But may I simply say that this has been an extraordinary panel.

The CHAIRMAN. I thank you gentlemen very much indeed for being with us. We apologize for the couple of delays, and we appreciate your help tremendously.

At this point, this series of hearings on these two treaties are adjourned.

[Whereupon, at 12:33 p.m., the committee adjourned.]

APPENDIX

Prepared Statement of Robert B. Barker

Mr. Chairman, I am pleased to have this opportunity to present the views of the Department of Defense on the subject of the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET).

Since 1976, the primary concern of the Department of Defense with respect to the TTBT and the PNET has been to ensure that these agreements place equal constraints on the nuclear weapon development programs of the U.S. and the Soviet Union. Such assurance requires that the agreements be effectively verified. The Department therefore fully supports the President's request for the Senate's advice and consent to the ratification of the TTBT and PNET, subject to the condition that the President shall not proceed with ratification until the U.S. and the Soviet Union have concluded additional protocols or agreements which would be integral parts of the treaties and which would provide for effective verification of the treaties, including the right of each side to conduct accurate, direct, hydrodynamic yield measurements at the site of all nuclear detonations of the other side which otherwise might appear to have yields in excess of 150 kilotons.

Perhaps, too little understanding exists as to why effective verification of these treaties is absolutely necessary. I therefore would like to focus my remarks today on this central question.

Arms control agreements are not an end unto themselves; along with necessary defense modernization programs, they are part of a mutually reinforcing approach to preserving Western security and increasing stability. Thus, the TTBT and PNET, like other aspects of arms control, must be judged in light of their contribution to our overall national security requirements and objectives, including a more peaceful and secure world.

Turning now to the treaties at issue, I must emphasize that the U.S. decision in 1976 to respect the 150-kiloton threshold of the as yet unratified TTBT has had an impact on our ability to meet essential defense requirements to ensure our national security. The TTBT has had this impact by limiting the flexibility of our nuclear testing program in ways that we otherwise would not have limited ourselves, given the incessant Soviet hardening program and their massive buildup in offensive and defensive capabilities since the TTBT was signed in 1974. Indeed, contrary to the expectations of some in the mid- to late-1970s, key Soviet military, leadership, and economic assets -- which we must be able to hold at risk if deterrence and stability are to be maintained -- are increasing significantly in hardness. Hence, the U.S. requirement for high-yield weapons has not diminished as some expected in the wake of the 1972 ABM Treaty and Interim Agreement on the Limitation of Strategic Offensive Arms.

Along with the continuing U.S. requirement for high-yield weapons comes a requirement to test these weapons at full yield to ensure the highest possible confidence in their reliability and effectiveness. But this area is where we have had to make trade-offs, where we have assumed certain risks and have been prevented from pursuing modern high-yield technologies in order to live within the TTBT regime.

Our last high-yield test took place in 1976 -- before the 150-kiloton TTBT limit took effect. This means that to accomplish our necessary defense modernization programs -- including nuclear weapons for the Air Launched Cruise Missile, Peacekeeper missile, Trident submarine, B-1 bomber, and small ICBM -- we have deployed, or will deploy, high-yield weapons without full-yield tests. Thus, with the passing years, we have been placed in the position of certifying that our newest weapons, which increasingly differ from their tested precursor, will still work as intended based upon the expert judgment of our weapon designers, and not upon validation by a full-yield test. In other words, our confidence that our weapons -- which we must rely on for our nuclear deterrence well into the 21st century -- will remain safe, effective, and reliable will not be as high as it would have been in the absence of the TTBT's constraints. This erosion of confidence will be compounded as the number of our superb weapon designers who have had direct experience with high-yield testing decreases over time.

Yes, we have accepted these risks. Yes, we believe we can meet all requirements for new high-yield weapons which we can now foresee. Yes, we have evaluated the risks and, on balance, they have been judged to be acceptable. We cannot guarantee, however, that this will forever be the case.

In this connection, I would note that Article V of the TTBT provides for a five-year duration with automatic extension for successive five-year periods, unless either party notifies the other of its termination no later than six months prior to the treaty's expiration at the end of a given five-year period. There also is a clause that protects our right to withdraw in the event of a threat to our supreme national interests. We must recognize, however, that exercising these clauses would require a consensus which, in fact, might be very difficult to achieve.

As I have indicated, acceptance of the constraints on our deterrent capabilities imposed by the 150-kiloton threshold requires that the Soviet weapons program is similarly constrained and that we have effective means to assess Soviet compliance or noncompliance with this threshold. If we do not provide for such means, if we leave the Soviets free to exploit verification uncertainties to carry out even a few nuclear weapon tests significantly above the 150-kiloton level, we would raise the inherent risks to U.S. security to unacceptable levels. We know from experience that even one nuclear weapon test can make the difference between having confidence or not having confidence in a stockpiled warhead. If the Soviets were to violate the 150-kiloton limit of the TTBT -- and based on the totality of the evidence, seismic as well as nonseismic, we believe they likely have done so on a number of occasions -- they could maintain high confidence in their existing high-yield designs, and better maintain and even improve the high-yield expertise of their nuclear weapon design and production establishment. In short, their confidence in their ability to strike our retaliatory forces could increase, to the detriment of the Free World. Even if we had assurance that the Soviets were complying with the 150-kiloton limit, it is possible that their approach to nuclear weapon design is such that the constraint may be less of a risk to them than it is to us.

I believe Senator Glenn very succinctly underscored the importance of effective verification during this Committee's hearings in 1977 on the TTBT and PNET. He then stated: "I will vote against anything around here that cannot be verified because I do not trust the people with whom we are dealing any more than does anyone else...As long as we make an agreement and know when they (the Soviets) violate it, then we are not in bad shape and we have made some progress. But just to take a 'pig-in-a-poke' assumption that they are going to abide by something because we abide by it is not realistic."

As President Reagan and others in the Administration repeatedly have stated, we cannot effectively verify Soviet compliance with the 150-kiloton limit of the TTBT and PNET without on-site, direct measurements. In their current forms, the treaties are a "pig-in-a-poke." The seismic techniques that we currently must rely on to estimate yields of Soviet nuclear detonations are assessed to have about a factor-of-two uncertainty for nuclear weapons tests, and an even greater uncertainty level for Soviet peaceful nuclear explosions. This uncertainty factor means, for example, that a Soviet test for which we estimate a yield of 150 kilotons may have, with 95 percent probability, an actual yield as high as 300 kilotons -- twice the legal limit -- or as low as 75 kilotons. And despite the optimistic predictions and efforts of seismologists over the years, they have no empirical data, no hard data on which to base their estimations of yields of Soviet nuclear detonations; they only have estimates built on extrapolations from tests and geological media far from the Soviet Union. Moreover, the seismic yield estimation process will always be subject to residual systematic errors unknown to us but known to, and possibly exploitable by, the Soviets. They could use their accurate knowledge of their geology and certain emplacement techniques to systematically conduct nuclear tests in a manner that would reduce seismic signals -- in effect, cloaking a nuclear test with a yield above the legal limit such that it appears to us as being within the limit.

Even if the verification measures now in the TTBT and PNET were implemented, the treaties still would not be effectively verifiable. The TTBT, for example, provides for an exchange of data, but does not provide for independent confirmation of the data by the U.S.

In 1981, when an eminent former member of this Committee learned of the factor-of-two uncertainty level in our estimates of Soviet nuclear weapon test yields and the question was raised whether we should ratify the treaties on this basis, his reaction was quick and correct: "Absolutely not." He encouraged us to look for a much improved verification means.

Well, we have found that better way -- a method we have used to determine the yields of our own nuclear tests. Specifically, the U.S. CORRTEX system of direct, hydrodynamic yield measurement, when used directly to measure a Soviet nuclear detonation, will have a random error no larger than 30 percent, which corresponds to lowering the uncertainty factor from about 2 to 1.3. The practical, effective, and proven CORRTEX system would accomplish this sharply reduced uncertainty level without danger of compromising sensitive information about the nature or performance of the nuclear device whose yield is measured, and without the systematic-error uncertainties inherent in seismic methods.

We recognize that even CORRTEX will not eliminate all verification uncertainties. Its use, however, can significantly reduce those uncertainties. Its use can provide a timely basis for judgments on any Soviet violations, thereby enabling the U.S. to counter threats posed to our security. Of equal importance, CORRTEX-like measures will alleviate the situation which exists today, where the relationship between the U.S. and the Soviet Union is clouded by a constant exchange of demarches between our governments, each accusing the other of having violated the TTBT. For these reasons, direct, on-site, hydrodynamic yield measurements are indispensable to effective verification of compliance with the 150-kiloton limit of the TTBT and PNET. On this basis, the President has stated that if the Soviet Union were to agree to the use of CORRTEX to achieve effective verification of the treaties, he would be prepared to move forward on their ratification.

The U.S. has met with the Soviets on three separate occasions in 1986 at the Geneva Nuclear Testing Experts Meetings. I have been privileged to head the U.S. delegation. The U.S. objective throughout has been to establish effective verification of the TTBT and PNET. The U.S. has presented extensive technical briefings on CORRTEX to the Soviet experts. The technical interchange was significant. We also have reiterated the President's invitation to Soviet government experts to come to the U.S. test site, where they could observe CORRTEX in use on a U.S. nuclear weapon test and clear up any remaining questions. We have prepared the basis for the serious negotiation of the necessary verification improvements of the TTBT and PNET. We are continuing our efforts, however, to elicit a constructive Soviet approach. We note that shortly after the Reykjavik meeting, General Secretary Gorbachev indicated that the Soviet Union is ready to address "perhaps even on a top-priority basis," the TTBT and PNET treaties.

In conclusion, Mr. Chairman, I sincerely hope that the increased attention to nuclear testing issues over the past year or so, in both Congress and among the public, has led to a better appreciation of the direct and profound importance of these issues to the national security of the U.S. and our allies. As the Administration -- beginning with President Reagan -- has made clear, the maintenance of a strong nuclear deterrent has for four decades ensured the security of the Free World. As long as the U.S. and our allies must rely on nuclear weapons to deter Soviet aggression -- and that will be the case for the foreseeable future -- nuclear testing will be required to ensure the the credibility of our deterrent. At the same time, I can assure you that the U.S. exercises all prudent restraint in the testing program. We test no more often than is necessary. And the U.S. test program has been consistent with our obligations under the TTBT.

This Administration long has had a constructive and practical agenda in the area of limitations on nuclear testing, and the place to start is by introducing effective verification mechanisms into existing agreements -- i.e., the TTBT and PNET. Without effective verification, we would incur unacceptable military risks and kindle suspicion and instability. With effective verification, we would lay the groundwork for mutual confidence in the agreements and, we hope, enhance stability. U.S.-Soviet agreement that provides for effective verification of the treaties is the necessary first step that would allow us, as the President has pledged, to ratify the treaties and then -- in association with a program to reduce and ultimately eliminate all nuclear weapons -- to engage in negotiations on ways to implement a step-by-step parallel program of limiting and ultimately ending nuclear testing.

We welcome Congressional support for this agenda.

Thank you.

Prepared Statement of Lt. Gen. Dale A. Vesser

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE,

I APPRECIATE THIS OPPORTUNITY TO PROVIDE THE VIEWS OF THE JOINT CHIEFS OF STAFF ON THE RATIFICATION OF THE THRESHOLD TEST BAN TREATY (TTBT) AND THE PEACEFUL NUCLEAR EXPLOSIONS TREATY (PNET).

THE CHAIRMAN AND THE JOINT CHIEFS SUPPORT, IN PRINCIPLE, RATIFICATION OF THESE TREATIES. THAT SUPPORT, HOWEVER, IS WITH THE UNDERSTANDING THAT THE IMPROVED VERIFICATION MEASURES BEING CONTEMPLATED ARE INCORPORATED INTO THE TREATIES AS PROTOCOLS OR OTHER APPROPRIATE CODICILS PRIOR TO RATIFICATION AND THAT APPROPRIATE SAFEGUARDS ARE ADOPTED TO REDUCE, IN SO FAR AS POSSIBLE, THE MILITARY RISKS ASSOCIATED WITH THESE TREATIES.

THE LIMITED TEST BAN TREATY (LTBT) WHICH WAS RATIFIED IN 1963 WAS THE FIRST STEP IN LIMITING NUCLEAR TESTING. THAT TREATY PROHIBITS TESTING IN THE ATMOSPHERE, IN OUTER SPACE AND UNDER WATER. UNDERGROUND TESTS WERE ALSO PROHIBITED IF THOSE TESTS CAUSED "RADIOACTIVE DEBRIS TO BE PRESENT OUTSIDE THE TERRITORIAL LIMITS OF THE STATE UNDER WHOSE JURISDICTION OR CONTROL" THE EXPLOSIONS WERE CONDUCTED.

WHILE THE LTBT WAS BEING NEGOTIATED THE JOINT CHIEFS OF STAFF RECOGNIZED THAT THERE WERE MILITARY RISKS ASSOCIATED WITH A TREATY THAT RESTRICTED OUR FLEXIBILITY IN RESPONDING TO CHANGES IN THE THREAT WE FACE. IN ORDER TO REDUCE THE ASSOCIATED MILITARY RISKS, THE JOINT CHIEFS RECOMMENDED SAFEGUARDS WHICH

WERE SUBSEQUENTLY ADOPTED DURING THE RATIFICATION PROCESS FOR THE LTBT.

FOLLOWING RATIFICATION OF THE NUCLEAR NON-PROLIFERATION TREATY (1968), UNITED STATES REPRESENTATIVES NEGOTIATED THE TTBT (SIGNED IN 1974) AND THE PNET (SIGNED IN 1976). THESE TREATIES LIMIT THE YIELD OF INDIVIDUAL NUCLEAR EXPLOSIONS TO 150 KILOTONS. THE PROVISIONS OF THE TTBT AND PNET WERE UNDERTAKEN TO ESTABLISH A COMPREHENSIVE SYSTEM OF REGULATIONS WHICH WOULD GOVERN ALL UNDERGROUND NUCLEAR EXPLOSIONS, BOTH THOSE FOR WEAPONS DEVELOPMENT PURPOSES AND THOSE FOR PEACEFUL APPLICATIONS.

DURING HEARINGS ON THE TTBT AND PNET BEFORE THIS COMMITTEE IN 1977, THE REPRESENTATIVE OF THE JOINT CHIEFS OF STAFF STATED THAT THE MILITARY RISKS ASSOCIATED WITH FURTHER CONSTRAINTS PLACED ON US NUCLEAR TESTING BY THESE TREATIES COULD BE REDUCED TO ACCEPTABLE LEVELS THROUGH ADOPTION OF APPROPRIATE SAFEGUARDS. AT THAT TIME THE CHIEFS BELIEVED THAT THE APPROPRIATE SAFEGUARDS COULD BE ARRIVED AT THROUGH SIMPLE MODIFICATIONS TO THOSE SAFEGUARDS ADOPTED FOR THE LTBT.

IN REVIEWING THE TREATIES FOR THIS SET OF HEARINGS, THE JCS HAVE TAKEN INTO ACCOUNT THE EXPERIENCE OF THE TEN YEARS SINCE THE TREATIES WERE SIGNED.

DURING THOSE INTERVENING YEARS, IT HAS BECOME APPARENT THAT THE TREATIES ARE NOT VERIFIABLE IN THEIR CURRENT FORM AND THAT IT WAS LIKELY THE SOVIETS HAVE VIOLATED THE 150 KILOTON LIMIT OF THE THRESHOLD TEST BAN TREATY. FOR THIS REASON PRESIDENT REAGAN MADE

EFFECTIVE VERIFICATION OF THE TWO TREATIES THE HIGHEST PRIORITY IN THE AREA OF NUCLEAR TESTING LIMITATION. THE JCS FULLY SUPPORT THAT PRIORITY AND THE PRESIDENT'S INITIATIVE OF SUBMITTING THESE TREATIES FOR ADVICE AND CONSENT WITH A RESERVATION TO ENSURE THAT THEY ARE NOT RATIFIED AND DO NOT TAKE EFFECT UNTIL HE IS ABLE TO CERTIFY THAT THE US AND THE SOVIET UNION HAVE CONCLUDED ADDITIONAL PROTOCOLS OR OTHER AGREEMENTS, INCLUDING PROVISIONS FOR DIRECT, ACCURATE YIELD MEASUREMENTS, SO THAT THE 150 KILOTON LIMIT OF THE TREATIES IS EFFECTIVELY VERIFIABLE. ONLY THROUGH EFFECTIVE VERIFICATION WILL THE UNITED STATES HAVE CONFIDENCE THAT THE SOVIETS ARE BEING HELD AS CLOSELY AS POSSIBLE TO THE SAME CONSTRAINTS THAT THE UNITED STATES HAS LIVED WITH SINCE 1976.

WHILE REMAINING IN COMPLIANCE WITH THE TERMS OF THE THRESHOLD TEST BAN TREATY, THE UNITED STATES HAS BEEN PREVENTED FROM EXPLORING ADVANCED HIGH YIELD TECHNOLOGIES THAT WOULD REQUIRE TESTING ABOVE THE 150 KILOTON LIMIT. THE UNITED STATES HAS ALSO BEEN UNABLE TO CONDUCT FULL YIELD CONFIDENCE TESTS OF SOME STOCKPILED WEAPONS. LIKEWISE, DURING THIS PERIOD, THE NUMBER OF US NUCLEAR TEST AND DESIGN PERSONNEL WHO HAVE EXPERIENCE IN HIGH YIELD TESTING HAS DECLINED, LIMITING OUR ABILITY TO TEST ABOVE 150 KILOTONS SHOULD A REQUIREMENT ARISE.

ALTHOUGH OUR EVENTUAL GOAL IS TO REDUCE THE NUMBER OF NUCLEAR WEAPONS AND OUR DEPENDENCY ON THEM FOR DETERRENCE, THE KEYSTONE OF OUR DETERRENT STRATEGY NOW, AND FOR THE FORESEEABLE FUTURE, IS THE PREVENTION OF WAR BY REMOVING ALL INCENTIVES FOR AGGRESSION AGAINST THE UNITED STATES AND OUR ALLIES BY PROMISING A

DEVASTATING RETALIATION TO ANY ATTACKER. WE HAVE ENDEAVORED TO ACCOMPLISH THIS GOAL FOR MOST OF THE POSTWAR PERIOD BY POSSESSING A CREDIBLE NUCLEAR DETERRENT THAT IS BOTH EFFECTIVE AND RELIABLE. TO MAINTAIN THE CREDIBILITY OF THIS NUCLEAR DETERRENT, TESTING IS REQUIRED. IN ADDITION, NUCLEAR TESTING ENABLES US TO ENSURE THAT OUR NUCLEAR WEAPONS ARE SAFE, THAT BOTH OUR NUCLEAR AND NON-NUCLEAR WEAPONS AND EQUIPMENT WOULD FUNCTION IN A NUCLEAR ENVIRONMENT, THAT WE CAN KEEP AHEAD OF SOVIET EFFORTS TO NEUTRALIZE OUR DETERRENT, AND THAT THE SOVIETS DO NOT SURPRISE US WITH BREAKTHROUGHS WHICH MIGHT ALTER THE STRATEGIC BALANCE.

AS THESE TREATIES ARE BEING RECONSIDERED, THE JOINT CHIEFS OF STAFF ONCE AGAIN POINT OUT THAT IT IS IMPERATIVE THAT APPROPRIATE SAFEGUARDS BE ADOPTED TO REDUCE THE MILITARY RISKS ASSOCIATED WITH THESE TREATIES. IN SUPPORT OF THIS OBJECTIVE, THE JCS HAVE FORWARDED TO THE SECRETARY OF DEFENSE, WITH A REQUEST THAT THEY BE FORWARDED TO THE PRESIDENT FOR INCLUSION IN THE RATIFICATION PROCESS, A REVISION OF THE SAFEGUARDS ADOPTED IN CONJUNCTION WITH THE LIMITED TEST BAN TREATY. THIS REVISION INCLUDES CONTINUED UNDERGROUND NUCLEAR TEST PROGRAMS CONSISTENT WITH TREATY LIMITATIONS, MAINTENANCE OF MODERN NUCLEAR LABORATORY FACILITIES, MAINTENANCE OF THE BASIC CAPABILITY TO RESUME NUCLEAR TESTS IN PROHIBITED ENVIRONMENTS AND YIELD RANGES, SHOULD THEY BE CONSIDERED ESSENTIAL, A VIGOROUS VERIFICATION PROGRAM, AND CONTINUED EMPHASIS ON INTELLIGENCE CAPABILITIES.

FURTHERMORE, BECAUSE ADHERENCE TO THE 150 KILOTON LIMIT OF THE THRESHOLD TEST BAN TREATY CONSTRAINS OUR ABILITY TO RESPOND

TO CHANGES IN THE SOVIET THREAT, THE REVISION OF THE LTBT SAFEGUARDS CALLS FOR THE CONDUCT OF AN INDEPENDENT US GOVERNMENTAL REVIEW AT PERIODIC INTERVALS TO DETERMINE IF RENEWAL OF THE TREATIES IS IN THE US NATIONAL INTEREST. THE JOINT CHIEFS OF STAFF HAVE ADDED THIS PROVISION BECAUSE ALTHOUGH THE UNITED STATES HAS BEEN ABLE TO MEET THE SOVIET THREAT WHILE REMAINING IN COMPLIANCE WITH THE CONSTRAINTS OF THE THRESHOLD TEST BAN TREATY, AND WILL BE ABLE TO DO SO FOR THE CURRENT MODERNIZATION PROGRAM, WE CAN NOT PRECLUDE THE POSSIBILITY THAT SOVIET EFFORTS TO SUBVERT OUR DETERRENT MAY CREATE A SITUATION THAT REQUIRES THE UNITED STATES TO TEST ABOVE THE 150 KILOTON LIMIT.

IN SUMMARY, I BELIEVE THAT WITH THE ADDITIONAL VERIFICATION MEASURES BEING CONTEMPLATED AND ADOPTION OF ADEQUATE SAFEGUARDS, RATIFICATION OF THE TREATIES WOULD BE SUPPORTABLE BY THE JOINT CHIEFS OF STAFF.

Prepared Statement of Dr. James H. McNally

When I was on the delegation that negotiated the Threshold Test Ban Treaty, I did not anticipate playing a role in hearings on the advice and consent process twelve years later. Nevertheless, I am pleased that the central issue under consideration today is the requirement for means of effective verification for both the Threshold Test Ban Treaty and the Peaceful Nuclear Explosion Treaty.

I share the feeling expressed by the late head of the negotiation delegations for both Treaties, Ambassador Stoessel, in his House Foreign Affairs testimony last February. "At the time when the TTBT and PNE agreements were negotiated, it was felt that the procedures regarding exchange of information called for in the Treaties would be adequate to provide verification that the limits called for in the agreement would be observed. In the years since the negotiations--developments have taken place which place this conclusion in doubt."

I want to begin by placing these treaties, and the question of their ratification, in the broad context of our arms control effort. I think we have before us an opportunity to advance substantially the cause of arms control, if we do our job well. Conversely, I believe we can do great harm to the cause of arms control, and our national security, if we do our job poorly.

Let me, first, characterize what I see as the positive opportunity. If we are careful and patient, Congress and the Executive Branch working together can use these two treaties as powerful incentives in our negotiations with the Soviets to create a major and needed improvement in arms control verification. That improvement, if it is achieved, will mark a serious advance not only for our negotiations on testing, but for arms control as a whole. Why? Because verification has always defined the outer limit of what we can achieve in this business. Verification has always been a key part of the problem we face in negotiations with the Soviets on nuclear arms control.

How would this opportunity work? The concrete measures needed to make the two treaties before us effectively verifiable would, if they were put in place, constitute major progress in negotiated verification provisions. By getting the Soviets to agree to such measures -- which we believe are essential to verify these treaties with confidence -- we would also have achieved a substantial strengthening of government-to-government cooperation between the United States and the Soviet Union in the arms control field. In fact, I would not quarrel with anyone who argued that such improvements in verification alone are a strong reason to work toward ratification of these treaties. They would advance the frontier of arms control and broaden future arms control opportunities.

I have spelled out what I see as the opportunity. Now let me describe the danger. If we are not careful we may abandon a principle that has steadfastly guided our arms control efforts since the very dawn of the nuclear age. In nuclear arms control, precisely drawn verification provisions and concerns must be a major part of any agreement with the Soviet Union to control, limit, or reduce nuclear weapons. This is a principle that, since the introduction of the Baruch Plan in 1946, has been held in common by Congress and the Executive Branch, by the Democratic and the Republican Administrations alike. It cuts across Party lines. It goes to the very core of the national interest. Verification must receive priority attention, before we decide on what kinds of controls are to be agreed upon and implemented.

Our experience in dealing with the Treaties that we are considering today has engendered ambiguity and uncertainty, when compliance with the explicitly agreed 150 kt threshold limitation has been examined. Because we are now at a point where we have a technically-feasible direct and yet nonintrusive method that can provide effective verification of the Treaties, we are now able to seek advice and consent of the Senate with an appropriate reservation.

The direct measurement technique, makes it possible to remove the major systematic uncertainties that are inherent in the seismic verification techniques, so optimistically adopted in 1974. With CORRTEX, the shock wave from a nuclear explosion may be measured and related directly to the yield at a distance of yards -- not hundreds or thousands of miles. The direct measurement removes questions of bias and calibration that are inherent in seismic methods. Direct measurement of nuclear explosions is the only proven method for removing concern regarding the systematic uncertainties involved in ascertaining compliance with the 150 kt limitation of the treaties under consideration. This uncertainty cannot be removed using, for example, indirect high explosive calibration tests because of the yield and geophysical differences with actual nuclear weapons tests.

What we propose would amount to a new area of cooperative and effective verification. The ground has been partially broken by the direct measurement technique already negotiated and incorporated into the Peaceful Nuclear Explosion Treaty, that is very similar to what we propose for the Threshold Test Ban Treaty. We know the Soviets have developed direct measurement instrumentation for their own purposes. There is no mystery concerning the physical principles of the technique.

Careful adaptation of the direct measurement technique into the treaties before us is necessary to achieve effective verification. With this nonintrusive but cooperative technique, we also move well beyond verification solely by National Technical Means. These two treaties and the opportunity they present to the United States and the Soviet Union to craft effective cooperative verification measures can potentially have the far reaching consequences for future arms control treaties and agreements that I outlined at the beginning of this testimony. As the President pointed out in his letter to Congress of August 14, 1986:

> The prospects for progress in arms control may be significantly enhanced if a regime of cooperation between the United States and the Soviet Union in development of verification capabilities consistent with national security objectives can be established.

In the area of nuclear testing limitations, as in all aspects of arms control involving the U.S. and the Soviet Union, agreements that limit military programs and thereby involve inherent risks to our security, must provide effective means to assess Soviet compliance with those agreements.

The effective verification we seek that utilizes CORRTEX direct measurement will enable us to acquire information necessary to a timely judgment on whether the Soviets are complying with the agreed obligations. Removing compliance ambiguity can only lead to greater confidence in our negotiated agreements, thereby enhancing stability. This ability to unambiguously detect violations also serves as a deterrent to those who would seek to undermine our security by violating treaty commitments.

The Administration has pursued the goal of effective verification of the Threshold Test Ban and Peaceful Nuclear

Explosion Treaties, since deciding that the CORRTEX direct measurement technique had the capability of removing concern with systematic contributions to compliance uncertainty in a nonintrusive way.

The discussions with the Soviets sought by the U.S. in 1983 and 1984 on verification of these treaties were repeatedly rebuffed by the Soviets. In 1986, however, we had a series of Nuclear Testing Experts Meetings with the Soviets. We enter 1987 with the expectation of continued discussions that will initiate negotiations on effective verification of the two treaties before us in the near future.

My colleagues have referred to the step-by-step parallel program -- in association with a program to reduce and ultimately eliminate all nuclear weapons -- of limiting and ultimately ending nuclear testing. Such a program has substantial advantages for the verification process by providing the opportunity to assess effective verification prospects carefully as the program progresses. Accompanied by assessments of the military and technical consequences, the benefits and risks of future steps can be established in an iterative fashion. Parallel progress in other arms control fora can be evaluated and the next steps defined. As the process moves forward we can achieve practical experience with measures that will enable us to define effective verification appropriate for each of the steps that might be taken.

Senate support for effective verification of the Threshold Test Ban and Peaceful Nuclear Explosion Treaties can help demonstrate the commitment of the United States to unambiguous and uncontroversial compliance with future Treaties and Agreements. We share Senator Pell's sentiment quoted in the press release announcing these hearings of hoping that our joint effort "will lead to mutually acceptable language which makes clear the commitment of both the Administration and the Senate to effective verification, allows the President flexibility in further verification negotiations with the Soviets, and affirms a mutual commitment to further constraints on testing and an ultimate end to all nuclear explosions."

Prepared Statement of H. Allen Holmes

INTRODUCTION

GOOD MORNING. MR. CHAIRMAN, I WELCOME THIS OPPORTUNITY TO APPEAR BEFORE YOU FOR THE PURPOSE OF ADDRESSING THE ADMINISTRATION'S REQUEST FOR THE SENATE'S ADVICE AND CONSENT -- WITH AN APPROPRIATE RESERVATION -- TO RATIFICATION OF THE THRESHOLD TEST BAN TREATY (TTBT) AND THE PEACEFUL NUCLEAR EXPLOSIONS TREATY (PNET). I AM PLEASED TO NOTE THAT ADMINISTRATION OFFICIALS AND MEMBERS OF THE SENATE STAFF HAVE HELD THOROUGH CONSULTATIONS ON THIS SUBJECT. I APPRECIATE THE COOPERATION OF YOUR PROFESSIONAL STAFF.

US NUCLEAR TESTING POLICY

UNITED STATES POLICY WITH RESPECT TO THE BROAD ISSUE OF NUCLEAR TESTING LIMITATIONS HAS BEEN CLEAR AND CONSISTENT THROUGHOUT THIS ADMINISTRATION. WE ARE COMMITTED TO THE ULTIMATE ATTAINMENT OF A TOTAL BAN ON NUCLEAR TESTING UNDER APPROPRIATE

CIRCUMSTANCES, A GOAL THAT HAS BEEN ENDORSED BY EVERY PRESIDENT SINCE PRESIDENT EISENHOWER.

BUT FOR THE PRESENT, THE UNITED STATES, ITS ALLIES, AND ITS FRIENDS DEPEND ON NUCLEAR WEAPONS FOR DETERRENCE. SO LONG AS WE MUST CONTINUE TO RELY ON A SECURE AND CREDIBLE NUCLEAR DETERRENT AS THE ULTIMATE GUARANTOR OF PEACE WITH FREEDOM, SOME LEVEL OF TESTING WILL BE NECESSARY TO ENSURE THE SAFETY, RELIABILITY, EFFECTIVENESS AND SURVIVABILITY OF OUR NUCLEAR WEAPONS. WE WANT TO MAKE PROGRESS IN THIS AREA, HOWEVER, AS THE PRESIDENT OUTLINED IN HIS LETTER OF LAST OCTOBER. WE ARE HERE TODAY TO TESTIFY IN SUPPORT OF THE ADMINISTRATION'S APPROACH TO NUCLEAR TESTING LIMITS.

HISTORY OF THESE TWO TREATIES

THE NEGOTIATIONS AND SUPPORT OF THESE TREATIES REPRESENT LONG AND SERIOUS EFFORTS BY SEVERAL ADMINISTRATIONS. THEY REFLECT THE CONSIDERED JUDGMENT OF SEVERAL PRESIDENTS THAT CAREFULLY STRUCTURED LIMITATIONS ON THE NUCLEAR WEAPONS DEVELOPMENT PROCESS, IF FULLY OBSERVED BY BOTH SIDES, ARE POSITIVE STEPS.

IN 1974 THE US AND THE SOVIET UNION NEGOTIATED THE THRESHOLD TEST BAN TREATY AND IN 1976 THEY SIGNED THE PEACEFUL NUCLEAR EXPLOSIONS TREATY. NEITHER OF THESE TREATIES HAS BEEN SUBSEQUENTLY RATIFIED BY EITHER THE UNITED STATES OR THE SOVIET UNION. SINCE 1983, THE PRESIDENT HAS SOUGHT VERIFICATION IMPROVEMENTS THAT WOULD ENABLE HIM TO MOVE FORWARD ON RATIFICATION.

FOR ITS PART, THE SOVIET UNION HAS CLAIMED THAT IF THE UNITED STATES WOULD RATIFY THE TTBT AND PNET AND IMPLEMENT THEIR VERIFICATION PROVISIONS, OUR VERIFICATION AND COMPLIANCE CONCERNS WOULD BE PROMPTLY RESOLVED. HOWEVER, OUR PROBLEMS WOULD NOT BE RESOLVED: LARGE UNCERTAINTIES WOULD REMAIN. FOR EXAMPLE, THE DATA TO BE EXCHANGED UPON RATIFICATION OF THE TTBT WOULD ITSELF BE UNVERIFIED. NOR WOULD THE VERIFICATION MEASURES IN THE PNET RESOLVE OUR CONCERNS ABOUT THAT TREATY.

RATIFICATION OF THE TTBT/PNET

WITH THE NECESSARY VERIFICATION IMPROVEMENTS WE SEEK, WE BELIEVE THESE TREATIES WOULD BE IN OUR NATIONAL INTEREST. THE TREATIES WERE NEGOTIATED AS IMPORTANT PARTS OF THE UNITED STATES' LONG-STANDING POLICY OF CONTROLLING THE DEVELOPMENT AND INHIBITING THE SPREAD OF NUCLEAR WEAPONS.

SPECIFICALLY, THESE TWO TREATIES, WHICH WE HAVE SCRUPULOUSLY OBSERVED FOR OVER A DECADE, PROHIBIT LARGER YIELD NUCLEAR EXPLOSIONS, SUCH AS TESTS ONCE CARRIED OUT BY THE SOVIETS AT LEVELS 15 TO 20 TIMES GREATER THAN 150 KT. THIS RESTRICTION IMPOSES A SIGNIFICANT QUALITATIVE LIMIT ON ONE ASPECT OF NUCLEAR WEAPONS DEVELOPMENT COMPETITION.

UNDER SECRETARY OF STATE FOR POLITICAL AFFAIRS, PHILIP HABIB TESTIFIED BEFORE THIS COMMITTEE ABOUT TEN YEARS AGO. HE SAID: "I BELIEVE THE POLITICAL BENEFITS WHICH CAN ACCRUE TO US BY THE RATIFICATION OF THESE TREATIES ARE AS SIGNIFICANT AS THE CONTRIBUTIONS WHICH THEY MAKE TO THE CONTROL OF NUCLEAR WEAPONS." FORMAL AGREEMENT TO THIS LIMITATION ON NUCLEAR TESTING, BY OURSELVES AND OUR PRINCIPAL ADVERSARY, WILL BE SEEN BY OTHER PARTIES AS A POSITIVE AND STABILIZING STEP. IT WILL BE VIEWED AS DEMONSTRATING LEADERSHIP IN THE CRITICAL TASK OF PEACEFULLY MANAGING OUR RELATIONSHIP WITH THE SOVIET UNION WHILE PROVIDING AN EXAMPLE OF SELF-RESTRAINT TO ALL.

IN ADDITION, RATIFICATION OF THESE TREATIES WILL BUILD CONFIDENCE AND MEET THE REASONABLE EXPECTATIONS OF OUR NEGOTIATING PARTNERS AND OTHERS THAT ARMS CONTROL NEGOTIATIONS WITH THE UNITED STATES WILL RESULT IN CONCRETE PROGRESS. MORE IMPORTANTLY, WE ARE HOPEFUL THAT RATIFICATION OF IMPROVED, VERIFIABLE AGREEMENTS WILL OPEN THE PATH TO MORE STABLE AND PREDICTABLE RELATIONS WITH THE SOVIETS. AS THE PRESIDENT SAID IN HIS LETTER REQUESTING YOUR ADVICE AND CONSENT, RATIFICATION OF IMPROVED TREATIES THAT ARE EFFECTIVELY VERIFIABLE IS A NECESSARY FIRST STEP TO FURTHER PROGRESS.

IF THE SOVIETS AGREE TO OUR PROPOSALS TO MAKE THE TREATIES EFFECTIVELY VERIFIABLE, WE WILL MOVE INTO A NEW AREA OF BILATERAL COOPERATION BETWEEN OUR GOVERNMENTS IN THE AREA OF VERIFICATION. FOR THE FIRST TIME BOTH COUNTRIES WILL ALLOW DIRECT, ON-SITE MEASUREMENTS AT NUCLEAR TESTING SITES. THIS WILL BE A BENEFICIAL PRECEDENT FOR OTHER ARMS CONTROL NEGOTIATIONS AS WELL AS A GOOD STEP TOWARD FURTHER LIMITATIONS ON NUCLEAR TESTING.

TTBT/PNET VERIFICATION IS U.S. HIGHEST PRIORITY

OVER THE PAST TWO YEARS WE HAVE PLACED THE HIGHEST PRIORITY IN THE AREA OF NUCLEAR TESTING LIMITS ON FINDING AN EFFECTIVE MEANS OF VERIFICATION OF THE 1974 THRESHOLD TEST BAN TREATY (TTBT) AND THE 1976 PEACEFUL NUCLEAR EXPLOSIONS TREATY (PNET). WE HAVE PROPOSED CONCRETE MEANS OF BUILDING CONFIDENCE BY EXTENDING A UNILATERAL AND UNCONDITIONAL INVITATION TO THE SOVIET UNION TO SEND EXPERTS TO MEASURE DIRECTLY THE YIELD OF A NUCLEAR TEST AT OUR TEST SITE.

IN MARCH OF 1986 THE PRESIDENT URGED THE SOVIET UNION TO JOIN THE U.S. IN DISCUSSIONS ON FINDING WAYS TO REACH AGREEMENT ON ESSENTIAL VERIFICATION IMPROVEMENTS OF THE TTBT AND PNET. HE INVITED SOVIET SCIENTISTS TO COME TO OUR NEVADA TEST SITE TO EXAMINE OUR PROPOSED VERIFICATION SYSTEM FULLY. HE SAID THE U.S. WOULD BE PREPARED TO MOVE FORWARD ON RATIFICATION OF THE TTBT AND PNET IF THE SOVIETS WOULD AGREE TO EFFECTIVE VERIFICATION.

THE PRESIDENT HAS UNDERTAKEN A SERIES OF ADDITIONAL, CONCRETE AND PRACTICAL STEPS:

-- AFTER SEVERAL YEARS OF TRYING TO ENGAGE THE SOVIETS IN EXPERT LEVEL DISCUSSIONS, AGREEMENT WAS FINALLY REACHED LAST SUMMER. A FIRST MEETING WAS HELD IN JULY, A SECOND MEETING WAS HELD IN SEPTEMBER AND A THIRD MEETING TOOK PLACE IN NOVEMBER.

-- ON OCTOBER 10, 1986, IN REYKJAVIK, THE PRESIDENT ANNOUNCED THAT AS A FIRST ORDER OF BUSINESS FOR THE 100TH CONGRESS, HE WOULD REQUEST THE ADVICE AND CONSENT OF THE SENATE TO RATIFICATION OF THE TTBT AND PNET, BUT WITH AN APPROPRIATE RESERVATION TO THE TREATIES, WHICH YOU HAVE, ENSURING THEY WOULD NOT TAKE EFFECT UNTIL THEY ARE EFFECTIVELY VERIFIABLE.

-- FURTHER, THE PRESIDENT SAID THAT ONCE OUR TTBT/PNET VERIFICATION CONCERNS HAVE BEEN SATISFIED AND THE TREATIES HAVE BEEN RATIFIED, HE WOULD PROPOSE THAT THE UNITED STATES AND THE SOVIET UNION IMMEDIATELY ENGAGE IN NEGOTIATIONS ON WAYS TO IMPLEMENT A STEP-BY-STEP PARALLEL PROGRAM -- IN ASSOCIATION WITH A PROGRAM TO REDUCE AND ULTIMATELY ELIMINATE ALL NUCLEAR WEAPONS -- OF LIMITING AND ULTIMATELY ENDING NUCLEAR TESTING.

IN OUR VIEW, THIS IS A MOST PRACTICAL AND SERIOUS APPROACH TO NUCLEAR TESTING LIMITATIONS. YET, DESPITE OUR EFFORTS, THE SOVIETS HAVE NOT AGREED TO IT. WE REMAIN HOPEFUL THEY WILL JOIN US. WE HAVE LEFT THE DOOR OPEN TO NEGOTIATION AND IN FACT, WE HAVE RECENTLY REITERATED THROUGH DIPLOMATIC CHANNELS OUR PROPOSALS FOR THE OPENING OF NEGOTIATIONS WITH THE SOVIETS IN JANUARY.

THE PRESIDENT'S PROPOSALS IN THE NUCLEAR TESTING AND OTHER ARMS CONTROL AREAS DEMONSTRATE OUR COMMITMENT TO ACHIEVING THE CONDITIONS NECESSARY FOR POSSIBLE ADDITIONAL LIMITATIONS ON NUCLEAR TESTING IN THE CONTEXT OF A PROCESS OF NUCLEAR ARMS REDUCTIONS. IT IS NOW UP TO THE SOVIET UNION TO MAKE A SIMILAR COMMITMENT, WHICH THEY CAN DEMONSTRATE BY NEGOTIATING IN GOOD FAITH ON THE PRESIDENT'S PROPOSALS FOR ESSENTIAL VERIFICATION IMPROVEMENTS TO THE EXISTING TREATIES.

MORATORIUM

SOME ARGUE THAT THESE TREATIES DO NOT GO FAR ENOUGH, THAT THE UNITED STATES SHOULD SEEK A MORATORIUM ON TESTING INSTEAD. I WANT TO MAKE A FEW COMMENTS ON THAT PROPOSITION. FIRST, AS I HAVE ALREADY SAID, NUCLEAR TESTING IS CRITICAL TO NUCLEAR DETERRENCE, AND DETERRENCE IS WHAT HAS KEPT THE PEACE IN THE ATLANTIC TREATY AREA FOR OVER FOUR DECADES. THAT IS A SINGULAR ACHIEVEMENT. ¶ SECOND, A MORATORIUM OR A CTB HAS NO EFFECT ON THE NUMBERS OR DEPLOYMENT OF NUCLEAR WEAPONS; MORE IMPORTANT, IT WOULD NOT AFFECT THE THREATS TO OUR SECURITY WHICH FORCED US TO ARM IN THE FIRST PLACE. MOREOVER, IT IS POSSIBLE THAT FOCUS ON A COMPREHENSIVE TESTING BAN WILL DIVERT ATTENTION AND ENERGY FROM THE PRACTICAL AND ACHIEVABLE STEPS OF ARMS CONTROL REPRESENTED BY THESE TREATIES. THESE TREATIES CAN ENHANCE STABILITY AND SECURITY NOW, RATHER THAN IN SOME DISTANT FUTURE, AND OPEN THE WAY TO THAT FUTURE IF THE SOVIETS WILL AGREE TO ADDRESS IT SINCERELY AND MEANINGFULLY. THEY CONSTITUTE A SIGNIFICANT STEP ALONG AN IMPORTANT PATH.

SAFEGUARDS

I WISH ALSO TO POINT OUT THE IMPORTANCE OF MAINTAINING ADEQUATE SAFEGUARDS IN CONJUNCTION WITH THESE TREATIES. WE

CONSIDER SAFEGUARDS ESSENTIAL TO ENSURING THE NATION'S ABILITY TO RETAIN THE TECHNICAL MEANS AND KNOWLEDGE NECESSARY TO SUPPORT THE NUCLEAR DETERRENT AND EXISTING AND FUTURE NATIONAL SECURITY POLICIES. A DESCRIPTION OF THESE SAFEGUARDS WILL BE SUBMITTED FOR THE RECORD AT THE CONCLUSION OF OUR TESTIMONY. THE MILITARY AUTHORITIES WHO WILL MAKE PRESENTATIONS TO THIS COMMITTEE ARE PREPARED TO GIVE FURTHER DETAILS REGARDING SAFEGUARDS.

CONCLUSION

IN CONCLUSION, WE THINK THERE ARE GOOD OPPORTUNITIES FOR PROGRESS ON ARMS CONTROL, INCLUDING NUCLEAR TESTING. SO FAR, HOWEVER, THE SOVIETS HAVE BEEN MORE INTERESTED IN THE GRAND GESTURE THAN IN PRACTICAL STEPS.

TO SUMMARIZE:

1) WE HAVE MADE IT ABSOLUTELY CLEAR THAT WE REQUIRE NUCLEAR TESTING FOR OUR SECURITY AND THE SECURITY OF OUR ALLIES. WE INTEND TO CONTINUE WITH OUR TESTING PROGRAMS.

2) A NUCLEAR TESTING MORATORUM IS UNACCEPTABLE. IT DIVERTS ATTENTION FROM THE REAL ISSUES.

3) WHAT IS NEEDED NOW IS TO ENHANCE CONFIDENCE IN VERIFICATION OF THE TTBT AND PNET. WE PLACE TOP PRIORITY ON THE ACHIEVEMENT OF A REASONABLE AND EFFECTIVE SYSTEM BY WHICH WE CAN VERIFY COMPLIANCE WITH THE THRESHOLD TEST BAN TREATY AND THE PEACEFUL NUCLEAR EXPLOSIONS TREATY. THE US HAS MADE A SERIES OF CONCRETE PROPOSALS TO THE USSR IN THIS REGARD.

4) WE ARE PREPARED TO OPEN NEGOTIATIONS WITH THE SOVIETS NOW. ONCE THESE TREATIES ARE EFFECTIVELY VERIFIABLE AND HAVE BEEN RATIFIED, WE WOULD PROCEED IN ACCORDANCE WITH THE STEP-BY-STEP PROCESS OUTLINED BY THE PRESIDENT IN REYKJAVIK IN OCTOBER.

5) WE SEEK THE SENATE'S ADVICE AND CONSENT TO THESE TWO TREATIES WITH AN APPROPRIATE RESERVATION.

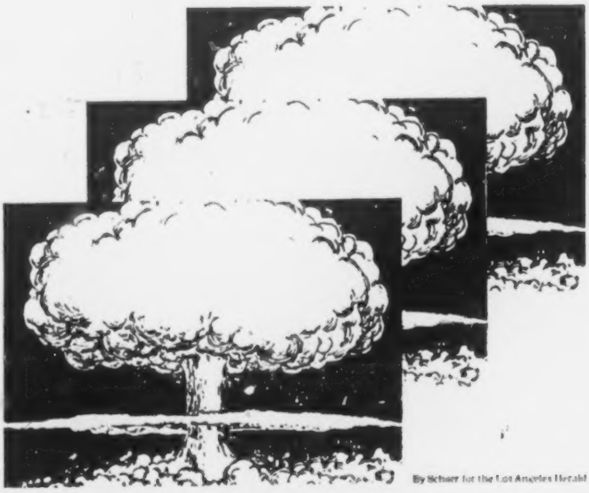
I ASK FOR YOUR CONTINUED SUPPORT IN OUR RESPONSIBLE APPROACH TO NUCLEAR TESTING LIMITATIONS.

Washington Post

-May 28, 1982

Larry Pressler

Two Treaties Ready to Go



By Schorr for the Los Angeles Herald

In moving toward a major breakthrough on strategic arms reductions, let us not forget the need for some modest but important steps in the interim. In this, consideration should be given to the ratification of two negotiated and signed accords limiting nuclear weapons tests, the Threshold Test Ban (TTB) and the Peaceful Nuclear Explosion (PNE) treaties.

The TTB and the PNE were negotiated and signed between 1974 and 1976 by the Nixon and Ford administrations. The TTB prohibits all weapons tests with yields greater than 150 kilotons. The PNE accord places the same constraints on so-called peaceful nuclear explosions. The Soviets have looked favorably toward PNEs and the United States has not. The United States has concluded that in most instances chemical explosives are sufficient for civil projects, and they avoid the radioactivity problems associated with PNEs. For this reason, the PNE treaty will have a greater impact on Moscow.

Some quarters in the bureaucracy advocate that we not ratify the TTB and PNE so that we can retain the option of testing high-yield weapons. But as Gen. David Jones, chairman of the Joint Chiefs of Staff, has indicated, there are no plans for such tests; nor is there any real need to conduct them. Assuring reliability of our current stockpile of weapons can be achieved under the 150-kiloton level. Moreover, the Soviets are in a better position to profit from a move toward high yield testing than is the United States. Moscow has ready-made facilities for such tests; we would have to start from scratch. There are few guarantees that Congress would fund such a program if we rather than the Soviets initiated testing above the threshold.

More important still is the likely impact of the 150-kiloton level upon the Soviet arsenal. The Soviets have long held a preference for multi-megaton weapons. These agreements would, therefore, be far more restrictive on them. If doubts on weapons reliability arose, this would first occur in Moscow. In the long term, moreover, the agreements might add to strategic stability. As new weapons came on line, their warheads would have to be tested to assure reliability. Likely Soviet doubts on the effectiveness of untested weapons might act as an incentive to move away from monster first-strike warheads.

Perhaps the most important provisions in these agreements deal with verification. The TTB provides for the exchange of geological and other test-related data required to assure compliance. The PNE's verification provisions are unprecedented. For the first time, the Soviets have agreed to on-site inspection.

The Reagan administration has made Soviet cooperation on the exchange of military data and on intrusive verification a litmus test of Soviet sincerity in arms restraint. The president's important strategic reductions initiative will depend on progress on these issues. The PNE and TTB offer Soviet concessions on both counts.

Support for ratification of these agreements has recently come from a broad spectrum of individuals, "hawks" as well as "doves." The group includes a stream of witnesses from the administration and the wider national security community who have testified before the Senate Foreign Relations Committee.

Since 1976 we and the Soviets have lived by these agreements—neither side has tested above the 150-kiloton level, and both have issued statements promising to adhere to the threshold as long as the other side does the same. But only ratification would bring the real benefits. Only then would the Soviets provide the data promised during negotiations and only then would they be bound to allow on-site inspection.

The writer is a Republican senator from South Dakota.

THE WHITE HOUSE
WASHINGTON
Reykjavik

October 10, 1986

Dear Mr. Chairman,

As I meet this week with General Secretary Gorbachev in Reykjavik, Iceland, I believe it is crucial that the Congress join with me in forging a strong bipartisan consensus on a nuclear testing policy that promotes our national security interests and advances long-standing U.S. arms control objectives.

As you are well aware, the Senate and House versions of the National Defense Authorization Act for Fiscal Year 1987 contain different amendments on the nuclear testing issue. The Senate bill includes non-binding language urging me, at the earliest possible date, to request advice and consent of the Senate (if necessary, with a reservation on the subject of verification) to the Threshold Test Ban and Peaceful Nuclear Explosions Treaties (TTBT/PNET) and to propose to the Soviet Union the immediate resumption of negotiations toward conclusion of a verifiable comprehensive test ban (CTB) treaty. The House bill would mandate a one-year moratorium on U.S. nuclear tests above one kiloton in yield, provided the Soviet Union demonstrates matching restraint and agrees to reciprocal in-country monitoring arrangements.

I fully recognize the difficult challenge you have faced in trying to reconcile these differing positions in the conference on this bill. However, I do not believe it is in the best interests of our Nation for this dispute to remain unresolved. I think it may be helpful if I were to identify some basic principles upon which I believe we all agree and to outline my plans for discussing this issue in Reykjavik.

First, let me emphasize that I am committed to the ultimate attainment of a total ban on nuclear testing, a goal that has been endorsed by every U.S. President since President Eisenhower. I am determined to take practical steps in the near future toward this goal.

Second, I am sure we are in full accord that any treaties with the Soviet Union in the arms control area -- whether they be treaties requiring reductions in deployed weapons or treaties limiting nuclear testing -- must be verifiable. In recent years, advances in technology have made possible methods of improved verification in the nuclear testing area that can and should be incorporated in both pending and any future nuclear testing agreements with the Soviet Union.

Third, I believe that we fully recognize that for over four decades we have relied upon nuclear weapons for the deterrence of war and that nuclear testing has been instrumental in ensuring the safety and reliability of these weapons. A CTB would necessarily require a completely different approach to meeting our crucial interests in the areas of nuclear weapons safety and reliability -- interests that will remain vital as long as the United States continues to depend on the threat of nuclear retaliation to deter aggression. Thus how one transitions to a total test ban regime is no less critical a concern than verification or any other national security issue related to an eventual implementation of a CTB.

With these principles in mind, I am prepared to take two important steps toward limiting nuclear testing. First, I intend to inform General Secretary Gorbachev in Reykjavik that as a first order of business for the 100th Congress, if the Soviet Union will, prior to the initiation of ratification proceedings in the Senate next year, agree to essential TTBT/PNET verification procedures which could be submitted to the Senate for its consideration in the form of a protocol or other appropriate codicil, I will request the advice and consent of the Senate to ratification of the TTB and PNE treaties. However, if the Soviet Union fails to agree to the required package of essential procedures prior to the convening of the 100th Congress, I will still make ratification of these treaties a first order of business for the Congress, with an appropriate reservation to the treaties that would ensure they would not take effect until they are effectively verifiable. I will work with the Senate in drafting this reservation.

Second, I intend to inform the General Secretary in Reykjavik that, once our verification concerns have been satisfied and the treaties have been ratified, I will propose that the United States and the Soviet Union immediately engage in negotiations on ways to implement a step-by-step parallel program -- in association with a program to reduce and ultimately eliminate all nuclear weapons -- of limiting and ultimately ending nuclear testing. These steps we can take in the near future -- steps which will show the world that the United States is moving forward.

I believe that the approach outlined in this letter is consistent with the broad purposes and objectives of the Congress with respect to limiting nuclear testing. I hope that this communication will prove constructive in assisting you to reach final agreement on a Fiscal Year 1987 defense authorization bill and will provide a foundation for a bipartisan consensus on this important policy issue.

Sincerely,

Ronald Reagan

The Honorable Barry Goldwater
Chairman, Committee on Armed Services
United States Senate
Washington, D. C. 20510

TO THE SENATE OF THE UNITED STATES:

Two treaties between the United States of America and the Union of Soviet Socialist Republics on (1) the Limitation of Underground Nuclear Weapon Tests, and the Protocol thereto, known as the Threshold Test Ban Treaty (TTBT) signed in Moscow on July 3, 1974, and (2) Underground Nuclear Explosions for Peaceful Purposes, and the Protocol thereto, known as the Peaceful Nuclear Explosions Treaty (PNET) signed in Washington and Moscow on May 28, 1976, were transmitted to the Senate by President Ford on July 29, 1976 with a view to receiving advice and consent to ratification. (Senate Executive N, 94th Cong., 2d Sess.) Although hearings were held a year later, the Senate itself has not acted on the treaties. I ask the Senate to consider these important treaties anew in light of developments that have taken place over the last decade.

On August 14, 1986, I transmitted to the Congress a comprehensive study which stated U.S. national security concerns as well as our views on necessary verification improvements to the TTBT and the PNET, in response to the requirements of Section 1003 of the FY 1986 Department of Defense Authorization Act (P.L. 99-145). I am enclosing a copy of this study and commend it to your attention.

The security of the United States and the entire free world, today and for the foreseeable future, depends on the maintenance of an effective and credible nuclear deterrent by the U.S. This is a considerable challenge, in light of continuing efforts by the Soviet Union to undercut the effectiveness of our deterrent. With the support of Congress we have succeeded in meeting this challenge, and together we must continue to do so in the future.

Today I am requesting per my October 10, 1986 letter that the Senate give advice and consent, subject to the condition set out below, to two pending treaties that have significant implications for Western security: the TTBT and PNET. These treaties have the common purpose of limiting individual nuclear explosions to no more than 150 kilotons. The TTBT, which prohibits nuclear weapon tests above 150 kilotons, places significant constraints on the efforts we may undertake in the U.S. nuclear test program to respond to Soviet nuclear and non-nuclear activities aimed at undercutting our deterrent. Hence, it is imperative that we have the necessary provisions that will make the TTBT effectively verifiable and thus assure ourselves that the Soviet Union is fulfilling its obligations and is thereby equally constrained.

Unfortunately, as I have frequently stated and the enclosed study makes clear, the TTBT and PNET are not effectively verifiable in their present form. Large uncertainties are present in the current method employed by the United States to estimate Soviet test yields. I have on several occasions reported to the Congress on the problems with Soviet compliance with the TTBT. Therefore, achieving Soviet agreement to improved verification measures that would provide for effective verification of these treaties has been my highest priority in the area of nuclear testing limitations.

As I stated in my March 14, 1986 letter to General Secretary Gorbachev, effective verification of the TTBT and PNET requires that we reduce the current unacceptable level of uncertainty in our estimates of the yields of nuclear tests. Indeed, leaders in previous Congresses have shared my view that the present large degree of uncertainty in such estimates is unacceptable, as well as my desire for sharp improvements. In this regard, we require -- and have conveyed to the Soviets that we require -- effective verification through direct, on-site hydrodynamic yield (CORRTEX) measurement of all appropriate high-yield nuclear detonations. Further, I informed General Secretary Gorbachev that, if the Soviet Union would agree to essential verification procedures for the TTBT and the PNET, I would then be prepared to request the advice and consent of the Senate to ratification of the treaties. Ratification of the treaties without such provisions would be contrary to the national security interests of the United States.

As written, the TTBT relies solely on teleseismic detection and yield measurement systems and on inadequate, and unverifiable data exchange. The Soviet Union has apparently had problems in correctly assessing the yields of U.S. nuclear tests. Despite our best efforts, the Soviet Union has so far not accepted our practical proposal for achieving the necessary verification improvement of the TTBT and the PNET. We have not yet found any alternative approach which equals the effectiveness of CORRTEX -- we are striving to achieve a yield-estimation accuracy of about 30 percent by this method. We have, nonetheless, advised the Soviets, at three Geneva nuclear testing experts meetings in 1986, that the U.S. is willing to consider any other direct yield measurement method the Soviets might propose, provided it is at least as capable (in terms of accuracy and non-intrusiveness) as CORRTEX. To date, they have not been forthcoming in proposing or explaining alternative verification techniques that would meet our requirements.

Recognizing the role of the Senate in the ratification process, I am therefore requesting that the Senate give its advice and consent to ratification of the TTBT and the PNET, subject to a condition in the following form:

> "The Senate's Resolution of advice and consent to ratification is subject to the condition that the President shall not proceed with ratification of the Treaty on Limitation of Underground Weapon Tests and the Treaty on Underground Nuclear Explosions for Peaceful Purposes until the President has certified to the Senate

> that the Union of Soviet Socialist Republics has concluded with the United States additional agreements expanding upon the obligations stated in Article II of the Treaty on Limitation of Underground Weapon Tests and including provisions for direct, accurate yield measurements taken at the site of all appropriate nuclear detonations so that the limitations and obligations of these treaties, *inter alia* the 150 kiloton limit, are effectively verifiable, and until such agreements have been submitted to the Senate, and the Senate has advised and consented to their ratification."

I am hopeful we can reach an agreement with the Soviet Union which will allow me to certify that the treaties are effectively verifiable. I will be prepared to ratify the TTBT and the PNET at such time as the condition cited above has been fulfilled.

Further, I informed the General Secretary in Reykjavik that, once our verification concerns have been satisfied and the treaties have been ratified, and in association with a program to reduce and ultimately eliminate all nuclear weapons, I would propose that the United States and the Soviet Union immediately engage in negotiations on ways to implement a step-by-step parallel program of limiting and ultimately ending nuclear testing.

The steps in this program would take into account our long-standing position that a comprehensive test ban is a long-term objective which must be viewed in the context of a time when we do not need to depend on nuclear deterrence to ensure international security and stability, and when we have achieved broad, deep, and verifiable arms reductions, substantially improved verification capabilities, expanded confidence-building measures, and greater balance in conventional forces.

Ronald Reagan

THE WHITE HOUSE,
January 13, 1987.

Special
Report
No. 152

Verifying Nuclear Testing Limitations: Possible U.S.-Soviet Cooperation

United States Department of State
Bureau of Public Affairs
Washington, D.C.

August 14, 1986

Following is the President's letter to Congress of August 14, 1986, transmitting an interagency study prepared by the U.S. Arms Control and Disarmament Agency.

Transmittal Letter

TO THE CONGRESS OF THE UNITED STATES

In response to the requirements of Section 1003 of the FY 1986 Department of Defense Authorization Act (P.L. 99-145), I am pleased to transmit this unclassified interagency study of possible avenues of cooperation between the United States and the Soviet Union in the development of verification capabilities consistent with national security restrictions.

The requirement under Section 1003 involves: "limited exchanges of data and scientific personnel," in general, and "joint technological effort in the area of seismic monitoring," in particular. Upon review of a number of possible scientific disciplines, it was concluded that in terms of this study, nuclear testing issues appear to offer the most promising avenues for such "scientific" cooperation and data exchange. Therefore, the attached study focuses its examination on matters relating to the verification of limitations in nuclear testing.

While the attached study focuses on nuclear testing limitations, it should be noted that in other arms control areas as well, the Administration believes that exchanges of information would, in addition to various monitoring provisions including types of on-site inspections, play an important role in establishing a verification framework.

In START [strategic arms limitation talks] and INF [intermediate-range nuclear forces], for example, areas of possible exchange of information might include the declaration of missile and launcher facilities, the numbers of missiles and launchers at such facilities, and information on the destruction of missiles and launchers that are in excess of agreed treaty limits. In the negotiations on Mutual and Balanced Force Reductions (MBFR), we have asked for an exchange of information, to be updated annually, on the structure of forces subject to MBFR limitations. At the Stockholm Conference on Confidence- and Security-Building Measures in Europe (CDE), we believe it important to have an exchange of information both on overall force structures and on specific forces participating in military activities. In chemical weapons arms control, we believe it important, among other things, to have a preliminary bilateral exchange of data on chemical weapons stockpiles and on production facilities as a confidence-building measure prior to the entry into force of a convention banning such weapons.

The prospects for progress in arms control may be significantly enhanced if a regime of cooperation between the United States and the Soviet Union in the development of verification capabilities consistent with national security restrictions can be established. The attached interagency study describes some possible avenues of cooperation that could produce benefits in the near term in the nuclear testing limitations area.

As indicated in the attached study, the United States has long sought a meeting with the Soviets to present our concerns about the verification provisions of the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET). The United States and the Soviet Union recently agreed to have experts meet to discuss issues related to nuclear testing.

This meeting of experts, which took place in Geneva July 25-August 1, allowed the United States to present its ideas and concerns to the Soviet Union and to hear Soviet views. At the meeting, the United States presented its views of verification improvements in existing agreements, which we believe are needed and achievable at this time. A follow-on meeting of U.S. and Soviet experts is scheduled for September. We hope the Soviet Union will join in a constructive dialogue.

RONALD REAGAN

THE WHITE HOUSE,
August 14, 1986

Interagency Study

POSSIBLE AVENUES FOR COOPERATION WITH THE SOVIET UNION IN THE DEVELOPMENT OF CAPABILITIES FOR VERIFYING COMPLIANCE WITH NUCLEAR TESTING LIMITATIONS

I. Introduction

Section 1003 of the FY 1986 Department of Defense Authorization Act (S. 1160) calls for an interagency study of "limited exchanges of data and scientific personnel" in general and "joint technological effort in the area of seismic monitoring" in particular. After reviewing a number of possible scientific disciplines, it was concluded that nuclear testing issues appear to offer the most promising avenues for scientific cooperation and data exchange. This study, therefore, focuses on matters relating to the verification of limitations in the area of nuclear testing.

II. Background

Effective means of verification are of critical importance to arms control. Our national security requires that we be able to assess with confidence compliance with any negotiated arms control agreements. Today, most of our major arms control agreements are monitored through what is known as national technical means of verification (NTM). While NTM has the primary benefit of being under the control of the verifying party, there are some particular applications—such as for strategic and intermediate-range nuclear forces, conventional and chemical forces, and nuclear testing—in which cooperative means of verification may be beneficial or even necessary.

Cooperative means can include various onsite inspection and data exchange measures or direct measurement schemes such as would apply to determining the yields of underground nuclear tests. Onsite inspection by observers and instruments may be able to play a role in deterring violations at agreed locations or "declared sites." The utility of onsite inspection is largely a function of its frequency and duration and whether, and at what costs, the activities monitored can be conducted at other times and places. Other considerations with regard to onsite inspection include the question of how the party being monitored calculates the risk of violations being uncovered and whether they could avoid *any* single inspection that would detect a violation. Thus, the past record of the inspected party is a vital consideration.

Data exchanges may be beneficial to provide a benchmark for assessing compliance. If, however, the verifying party does not possess a means of independently validating the data it receives, large uncertainties could still prevail, diminishing the utility of the exchange. Nevertheless, as the amount of data exchanged is increased, the uncertainty should decrease while the difficulty of concealing illegal activities increases.

Direct measurements have the benefit of allowing the verifying party to control the means of monitoring. Direct measurement is not perfect because it is limited by the accuracy of the instruments used and, as is the case for all monitoring methods, the ability of the inspected party to manipulate the evidence. Furthermore, direct measurement will not detect violations conducted at times and places when direct measurement equipment is not engaged and normally will not detect violations when special efforts are undertaken to conceal prohibited activities. However, even considering these limitations, direct measurement is much more definitive than any remote sensing method for determining the yields of Soviet nuclear tests.

The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Weapon Tests (Threshold Test Ban Treaty—TTBT) prohibits U.S. and Soviet underground nuclear weapon tests with yields greater than 150 kilotons (kt). The TTBT is a treaty signed by both parties but ratified by neither. Both the U.S. and the U.S.S.R. have separately stated that they would abide by the yield limitation. Furthermore, since neither party has made its intentions clear not to become a party, both signatories are obligated by international law to refrain from acts that would defeat the object and purpose of the treaty. At present, however, the United States cannot effectively verify Soviet compliance with the treaty. Moreover, the implementation of the verification measures set forth in the Protocol to the treaty (exchange of yield, date, time, depth, and coordinates for two nuclear weapon tests for calibration purposes from each geophysically distinct testing area and information on the geology of the testing areas), which would become effective upon ratification, will not provide this capability, since there is no way for the United States to independently verify the data exchanged, nor would the data, if validated, be sufficient to ensure effective verification.

Today, we monitor Soviet tests with seismic equipment located outside the U.S.S.R. In three presidential reports to Congress on Soviet noncompliance, the uncertainty in yield derived from seismic measurements, when taken into account, resulted in findings of only "likely violation," even though the seismic evidence indicates that a number of Soviet tests have central yield values above the 150 kt threshold. "Central yield" is defined as the yield corresponding to mean value of seismic body wave magnitudes for a particular nuclear test. While we judge that, at present, there is approximately a factor of two uncertainty in the yield estimates derived by seismic methods, there are reasons to suggest the uncertainty could be actually smaller (or conceivably larger). A factor of two uncertainty means, for example, that a Soviet test for which we derive a "central yield" value of 150 kt may have, with a 95% probability, a yield as high as 300 kt or as low as 75 kt.

As already mentioned, the verification provisions contained in the Protocol of the unratified TTBT would not reduce this level of uncertainty to an acceptable level. The U.S. Government has, therefore, continued its longstanding effort to obtain a means of monitoring that would substantially reduce our verification uncertainty. The history of the search for verifiable nuclear testing limitations will provide a backdrop for an understanding of the complicated and sometimes frustrating search for possible avenues of cooperation with the Soviet Union in the development of verification capabilities.

III. Historic Perspective On Nuclear Testing Limitations

One of the earliest proposals for nuclear testing limitations was presented in terms of a comprehensive test ban as part of a broader disarmament proposal made by the Soviets in the UN Disarmament Commission in May 1955. However, there was no movement in this area for the next 3 years. Early in the spring of 1958, President Eisenhower suggested to Soviet Premier Khrushchev that a group of technical experts meet to determine what specific control measures would be required to ensure compliance with a nuclear test ban. After several exchanges, Khrushchev agreed, and the Geneva Conference of Experts To Study the Possibility of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests was formed. Technical discussions between experts from the U.S.S.R., Poland, Czechoslovakia, Romania, the United Kingdom, France, Canada, and the United States began in July 1958.

On August 21, 1958, the Conference of Experts adopted a final report for consideration by governments. The report recommended a worldwide system of land control posts, shipborne posts, and regular and special air-sampling flights to monitor an agreement banning nuclear weapon tests in the atmosphere, underwater, and underground. Their report was accepted as the technical basis for political negotiations by the United States, the United Kingdom, and the U.S.S.R., and the Geneva Conference on the Discontinuance of Nuclear Weapon Tests began on October 31, 1958. The technical basis of the international control system was provided mainly by the reports of the 1958 Conference of Experts and a 1959 technical working group of the Geneva conference on the detection of high-altitude tests. These reports recommended a worldwide network of 160-170 land control posts, 10 shipborne posts, regular and special aircraft flights, and space satellites. The United States believed, however, that there was a serious risk that small underground explosions might remain undetected or be incorrectly identified as earthquakes.

The experts' report was technically limited in two respects: (1) it did not cover tests at more than 30-50 kilometers above the earth's surface, and (2) it did not have the benefit of the new seismic data obtained from the Hardtack underground test series carried out by the United States after the report was submitted. The new seismic data, submitted by the American delegation in Geneva in June 1959, showed that the proposed control system would have been less effective for detecting and identifying underground tests than the experts had believed.

At the request of the State Department, the President's Special Assistant for Science and Technology appointed a Panel on Seismic Improvement, headed by Dr. Lloyd Berkner, to study the new seismic data. The Berkner panel's report recommended a number of new techniques and proposed a research program to improve the capability of the verification system, described in the Geneva Conference of Experts' report, to detect and identify underground tests. The panel recommendations were the basis for much of the succeeding research in seismology and resulted in the development of new concepts in seismic stations, instrument arrays, computational techniques, and research into the phenomenology associated with seismic waves from explosions and earthquakes.

In the political negotiations, the United States tried unsuccessfully to persuade the Soviet Union to enter new technical discussion on the detection of high-altitude tests and the new seismic data. The Soviets took the position that technical questions had been settled at the 1958 Conference of Experts and any needed improvements in the control system could be made by the Control Commission after the treaty came into operation.

The participants at the Geneva Conference on the Discontinuance of Nuclear Weapon Tests agreed with the principle that onsite inspection would be necessary to clarify the source of unidentified seismic events. The United States believed that there could be up to 100 unidentified events per year of which approximately 20 would require inspection of the site. There was disagreement between the United States and the Soviets on the number of onsite inspections that would be permitted. The Soviets wanted to limit each party to two to three onsite inspections per year, when it was considered necessary. (Note: the Soviets, in effect, reserved for themselves a veto over onsite inspection requests.) Although the issues of numbers and mandatory versus voluntary onsite inspection were never resolved, the fact that the Soviets agreed in principle to the need for onsite inspection was widely hailed and was seen as setting a precedent for future arms control agreements. It was hoped that interim measures could be achieved that, with time, could lead to a more comprehensive agreement between the sides. The Soviets took the position that verification was less essential than reaching an agreement. The United States and the United Kingdom held that strict means of verification were required, that further study should be undertaken to assure that any agreement could be verified, and that this should be done before an agreement was signed.

On April 18, 1961, the United States and the United Kingdom submitted a complete draft treaty to the Geneva conference.[1] This proposal was based on one made by President Eisenhower in February 1960. The Anglo-American draft treaty included a commitment to cease tests in the atmosphere, underwater, at high altitudes, and underground (above seismic magnitude 4.75), and a control regime for detection and identification. Although the general characteristics of the international control system proposed in the Anglo-American draft treaty had long been accepted by both sides, the Soviet Union shifted its position on several vital verification features. For example, although the Soviets had agreed to 15 seismic stations within the U.S.S.R., they insisted that they would operate these sites. Again, even though the need for onsite inspection was recognized by the Soviets, the number of inspections proposed by the Soviets and the conditions under which they could be conducted were not satisfactory to the United States and the United Kingdom.

Throughout the test ban negotiations at Geneva from October 1958 to August 30, 1961, the United States and the United Kingdom faithfully observed a voluntary suspension of nuclear weapons tests, even though there existed no means of knowing with certainty, in the absence of an effective and workable international control system, that the Soviet Union was not increasing its nuclear capability by clandestine tests. In August 1961, the Soviet Union announced that it was resuming nuclear weapons tests and did so on September 1, 1961. The United States immediately condemned the Soviet action and reaffirmed its support for an agreement to end nuclear weapons tests under effective safeguards. On September 3, President Kennedy and Prime Minister Macmillan proposed that the Soviets agree "not to conduct nuclear tests which take place in the atmosphere and produce radioactive fallout." They stated that they were willing to rely upon existing means of detection, "which they believe to be adequate," and they did not suggest any additional controls. The Soviets at first rejected this offer.

Negotiations continued in various fora until finally, in 1963, Soviet interest in a ban that did not deal with underground tests emerged, even though they had rejected the U.S./U.K. offer previously. As a result, the United States, United Kingdom, and the U.S.S.R. agreed to the more limited goal of banning nuclear tests in all media except underground. This led to the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, usually referred to as the Limited Test Ban Treaty (LTBT).

While discussions continued in the 18 nation Committee on Disarmament, there was little further movement toward limiting underground nuclear tests until the 1974 summit meeting between the United States and the U.S.S.R. While the Soviets had originally called for negotiations on a comprehensive test ban, they agreed to consider a threshold treaty for underground nuclear testing. The threshold was to have been in terms of yield or possibly seismic wave magnitude. The United States initially proposed limiting tests to a certain value in body wave magnitude, but because body wave magnitude for a particular value of yield varies with test site location, the focus of the discussions was changed to yields. While this resolved the problem of the variability of body wave magnitude measurements, it introduced the problems associated with the accuracy of seismic techniques for the determination of yield. The TTBT was signed by the United States and the U.S.S.R. in July 1974.

The TTBT and its associated Protocol contain provisions for the exchange of geophysical data and announcing the yields of two explosions for calibration purposes in each geophysically distinct area (provisions which have not been implemented because the treaty has not been ratified). However, the treaty provides no mechanism by which one party could independently validate the accuracy of the data provided by the other party. Seismic techniques are inadequate to verify effectively the yields of Soviet tests. Prior to the signing of the TTBT, U.S. policy, as well as seismic research, had concentrated on a comprehensive test ban. Seismic research had been aimed at the problems of detecting and identifying low-yield nuclear tests with relatively less emphasis on determining yield.

While progress has been made in understanding the natural processes that affect yield estimation based on remote seismic measurement, the uncertainties in the yield estimation process cannot be sufficiently reduced without direct measurement of yields at the Soviet test sites. The Soviets, and some critics of existing U.S. policy in this country, have asserted that adequate verification will result from the exchange of data called for in the treaty. However, these data will be of limited value for verification purposes unless they can be independently verified by the United States. Even if the data were accurate and could be verified, they would not be sufficient to effectively verify Soviet compliance with the 150 kt threshold of the TTBT, because the limited data to be exchanged would not reduce the uncertainty in the seismic yield estimation process to acceptable levels.

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[1] See *Geneva Conference on the Discontinuance of Nuclear Weapons Tests: History and Analysis of Negotiations* (Department of State publication 7258, 1961).

The question of peaceful nuclear explosions (PNEs) was also addressed during 1971–74 and continued until the Treaty on the Limitation of Underground Nuclear Explosions for Peaceful Purposes, usually referred to as the Peaceful Nuclear Explosions Treaty (PNET), was signed in 1976. Since each individual nuclear explosion could not be greater than 150 kt, additional monitoring measures had to be negotiated for explosions conducted at locations other than at the designated weapons test sites and for salvos of explosions whose aggregate yield exceeded 150 kt. Provisions were included for onsite measurements of each explosion by downhole instrumentation, similar in result to the current CORRTEX [Continuous Reflectrometry for Radius versus Time Experiment] equipment, if the aggregate yield was planned to exceed 150 kt. Seismic instruments were also to be allowed in the test area if the aggregate yield was planned to exceed 500 kt. It is worth noting that even if the PNE Treaty were in force, the onsite measures would not have been implemented up to now because the Soviets apparently have not planned group explosions over any particular treaty-specified threshold which would trigger onsite inspection or installation of U.S. devices on Soviet territory.

Technical discussions on nuclear testing issues, principally related to a comprehensive test ban (CTB), have been held with the Soviets in the multilateral arena in Geneva. The United States presented papers at the Conference of the Committee on Disarmament (CCD) at least as far back as 1971 and again in 1973 and 1976. These papers discussed capabilities for discriminating between explosions and earthquakes, data from arrays of seismometers and networks of such stations, and various other seismology topics. There was, however, not much expert discussion of these U.S. contributions until the Ad-Hoc Group of Scientific Experts was formed in 1976.

One of the tasks of the Ad-Hoc Group of Scientific Experts was to describe a network of seismic stations that would provide data to the members for use in monitoring a CTB. Initially the Swedes, among others, attempted to establish a deliberative body within the CCD to conduct verification analyses. The United States did not want to rely on such a multinational group for verification decisions. As an alternative, the CCD, on the recommendation of the United States, formulated a plan for the exchange of seismic data and for conducting studies relating to those data. The Ad-Hoc Group of Scientific Experts selected an optimum network of seismic stations from CCD member states and evaluated its capability to provide data adequate for verification. An elaborate set of data parameters was agreed upon for reporting in a bulletin format. The World Meteorological Organization telegraph system was adopted for the exchange of these data bulletins. The exchange of complete seismograms, using digital techniques and satellite transmission, has been explored. Studies and experiments on these transmission techniques continue at the present time. It is significant, however, that throughout this period in which testing limitations have been of such concern, at no time have there been any joint projects of bilateral exchanges of data except for some limited discussions during the actual trilateral CTB negotiations.

In the summer of 1977, about 1 year after the conclusion of the PNE phase of the threshold treaty, the United States, the United Kingdom, and the U.S.S.R. began negotiations toward a comprehensive test ban. Initially, the United States and the U.S.S.R. had different views concerning the proposed duration of the treaty—the United States wanted a treaty of unlimited duration while the U.S.S.R. wanted a 3-year treaty that would continue depending on the actions of others, specifically France and China. By the summer of 1978, the United States revised its position and proposed a CTB of only 3 years duration.

Initially, the questions of seismic stations (numbers, kinds, and locations) were fairly open on both sides. As the negotiations on the number of seismic stations proceeded, the Soviets hardened their position on in-country seismic stations—demanding that they had to be nationally manned. The Soviets constantly raised their concern about unmanned stations or "black boxes." The United States eventually proposed 10 seismic stations in the Soviet Union in conjunction with a 3-year treaty. The U.S.S.R. said they would accept 10 stations in the U.S.S.R. provided that there would be 10 stations in the United States and 10 stations in the United Kingdom and its territories. This created a serious impasse. The United States and the United Kingdom felt that one station in the limited territory of the United Kingdom would be sufficient, but the Soviets would not budge. They took the position that equal participation required equal responsibilities. They further indicated that if 10–10–10 was not satisfactory, any other set of equal numbers would be acceptable. While the Soviets had apparently agreed in concept to both onsite inspection and incountry seismic stations, these issues were still unresolved when the negotiations were suspended in November 1980.

The United States has not resumed the trilateral CTB talks since they recessed in November 1980 because under present circumstances a CTB would be against the security interests of the United States and its allies and would not be effectively verifiable. In the existing environment, the security of the United States and our allies depends on a credible U.S. nuclear deterrent. In such a situation, where we must rely upon nuclear weapons to deter aggression, nuclear testing will be required. A comprehensive test ban remains a long-term objective of the U.S. arms control policy, but such a ban must be viewed in the context of a time when we do not need to depend upon nuclear deterrence to ensure international security and stability, and when we have achieved deep, broad, and verifiable arms reductions, improved verification capabilities, expanded confidence-building measures, and a greater balance in conventional forces.

The verification of a comprehensive test ban, and especially any testing moratorium such as proposed by the Soviet Union, remains a major problem. In the context of the verification procedures discussed (but not agreed) in the CTB trilateral negotiations, there would still be significant uncertainty about our ability to verify Soviet compliance, that is, to detect and identify with sufficient certainty a potentially significant level of clandestine testing. Our concerns are heightened by likely Soviet violations of the TTBT and by Soviet violation of the Limited Test Ban Treaty, the LTBT.

IV. Opportunity for Cooperative Measures

There are two distinct problem areas that can be addressed jointly by the United States and the U.S.S.R. The first deals with sufficiently accurate yield measurements that would allow effective verification of yield thresholds such as the 150 kt limit of the TTBT. Solution of this problem area would provide the basis for moving forward on ratification of the TTBT and the PNET. The second deals with the ability to detect and identify low-yield nuclear tests. This requires solution of the problem of detecting and identifying low-yield tests not only underground but also underwater, in the atmosphere, and in outer space. Programmed capabilities will greatly enhance our ability to detect and identify low-yield nuclear tests within the atmosphere, although there may remain some uncertainty regarding the country conducting such tests if they are conducted over remote areas. With these technological advances in hand and at a time when we do not need to depend upon nuclear deterrence to ensure international security and stability and when we have achieved deep, broad, and verifiable arms reductions, expanded confidence-building measures, and a greater balance in conventional forces, the conditions would exist for proceeding toward a treaty that would ban low-yield nuclear tests.

a. Verification of Yield Thresholds. As noted above, the provisions of the TTBT provide no mechanism for reducing the level of uncertainty of yield estimation to an acceptable level. (We believe that no method of yield estimation based only on information derived solely from seismic measurements or seismic theory can reduce the uncertainty to an acceptable level.) Uncertainties in the yield estimation process cannot be sufficiently reduced without directly measuring the yield of Soviet tests with instruments which are fundamentally much more accurate than seismic methods.

The President has stated that he is prepared to move forward on ratification of the TTBT and PNET if the Soviets would agree to the use of an effective verification system incorporating the CORRTEX method.

The most productive joint Soviet-U.S. discussions of monitoring measures would be those which would involve the technology and implementation procedures for direct yield measurement. The United States believes that it has identified in CORRTEX a measurement technique which will reduce the uncertainty in yield measurement to an acceptable level and will do so without danger of compromising other sensitive information about the nature or performance of the nuclear device whose yield is to be measured.

CORRTEX is a hydrodynamic yield measurement technique that measures the rate of propagation of the underground shock wave from an explosion. This technique uses an electric coaxial cable located in the device emplacement hole or in a nearby, parallel "satellite" hole. When the nuclear device is detonated, a shock wave propagates through the ground, crushing and shortening the cable. The rate by which the cable length changes is recorded by measuring the changing transit times of low energy electrical pulses sent down to and reflected from the cable end. This rate is a measure of the propagation velocity of the explosive shock wave through the ground which is, in turn, a measure of the yield of the nuclear explosion.

The electronic device that provides the timing signals is a battery-powered, suitcase-sized unit that may be remotely controlled. All equipment for power, recording, and data reduction can be contained in a small trailer.

CORRTEX has been shown to be accurate to within 15% (with 95% confidence) of more direct, radiochemical yield measurements for tests with yields greater than 50 kt. This is based on its use at the Nevada test site in over 100 tests with the sensing cable in the device emplacement hole and four tests with the sensing cable in a satellite hole. The accuracy of the technique is believed to be relatively independent of the geologic medium provided the satellite hole measurements are made in the "strong shock" region near the nuclear explosion. At greater separation distances, the medium becomes more important. A satellite hole separation distance of 14 meters (46 feet) is appropriate for a test near 150 kt.

CORRTEX is expected to be initially accurate to within 30% (with 95% confidence) of the actual yield at Soviet test sites for tests above 50 kt. An accuracy of 30% of the actual yield means, for example, that a test that produces CORRTEX measurements estimated to be associated with a "central value" yield of 150 kt, could, with a 95% probability, have a yield as high as 195 kt (150 kt plus 30% of 150 kt) or as low as 105 kt (150 kt minus 30% of 150 kt).

The Soviets were exposed to technology similar to CORRTEX during the PNET discussions. At that time, they indicated that they possessed similar technology. Therefore, a technical basis has already been established for the necessary discussions. The United States is prepared, as evidenced by the President's March 1986 offer, to demonstrate to Soviet technical experts how we would emplace CORRTEX instruments, how measurements are recorded, and how the data are analyzed. In any cooperative technical effort, the Soviet experts would have the opportunity to examine the CORRTEX data from a Soviet nuclear test in order to determine for themselves that no sensitive information, not relevant to TTBT verification, has been compromised. For their part, the Soviets would be permitted to bring any equipment they deemed necessary to measure the yield of the test.

Successful implementation of a direct-yield measurement regime for verification of the TTBT and the PNET will establish the principle of onsite inspection at declared facilities—in this case the site of nuclear tests. Joint Soviet-U.S. discussions to establish direct yield measurements will necessarily require negotiation of all the logistical aspects of such onsite presence, including the size and composition of the technical teams who would make measurements; agreement on the quantity of equipment which can be brought into the country; identification of allowed instrumentation; inspection of equipment by the party whose test is to be measured; establishment of housing, feeding, and transportation arrangements for the team making measurements; and procedures for sharing and transferring data from the country in which the test is to be performed.

Though not exhaustive, the above issues that would require negotiation are indicative of the long list of issues which must be addressed in making the transition from an agreement in principle to onsite inspection implementation. Any one of these elements, if not properly resolved, could frustrate the ultimate objective of the inspection regime. While not as glamorous as some aspects of arms control, the negotiation of such technical and logistical details is critical and may be extremely time consuming. Therefore, early joint Soviet-U.S. discussion of these issues can have a major impact on timely ratification of the TTBT and PNET.

b. Detection and Identification of Low-Yield Nuclear Tests. The second problem area, detection and identification of low-yield nuclear tests, is even more difficult because the solution requires effective monitoring in all environments—underground, underwater, in the atmosphere, and in outer space. Consequently, verification of any limitation of low-yield nuclear tests would require, at a minimum, the utilization of several techniques.

For example, detection and identification of low-yield nuclear tests will necessitate installation of an in-country seismic network and the implementation of onsite inspections. In addition, regional seismology (operating distances up to 2,000 kilometers from the source) will be a critical technology for the detection of underground tests. Measurement techniques for the collection and detection of atmospheric nuclear explosion debris will still require some refinement when working at or near levels of naturally occurring background radiation. Further development of hydroacoustic techniques could contribute to detection of small nuclear tests in remote ocean areas.

Recognizing the full scope of the problem of detecting and identifying low-yield nuclear tests in all environments, which must be solved, this paper will address only one part of the problem—monitoring low-yield *underground* nuclear tests—because this is the area where the United States believes that cooperation with the U.S.S.R. would be the most productive.

The requirements for in-country monitoring stations have been discussed with the Soviets in many fora since the late 1950s (see the "Historical Perspective" section). There remain several areas in which seismic monitoring can be profitably addressed by Soviet and U.S. technical experts. Further work may strengthen the basis for seismic detection and identification of low-yield nuclear tests in advance of the achievement of the other criteria which must be met before the United States could consider a comprehensive test ban to be in its national interest.

It is assumed that whatever the level of detection of seismic events, there will be some events detected whose origin (e.g., nuclear test, earthquake, chemical explosion) will be uncertain—unidentified (i.e., unresolved as to their origin) events. While improvements in seismic monitoring devices could be expected to provide additional data that could identify some of the events that cannot be identified at current sensitivity levels, the net effect of improvements in sensitivity will be to increase the number of unidentified events.

Onsite inspection, as a concept, is also used to describe inspections conducted to remove ambiguity when information from other sources indicates that a potential violation of a treaty in force may have already occurred. However, onsite inspection will only be useful when the precise location of the ambiguous event can be determined. Onsite inspection could contribute to identification of the source of surface or near-surface explosions, where surface disturbances would clearly indicate the location. For small underground explosions, it would be nearly impossible to locate the source with sufficient precision to permit the verifying party to drill into the cavity created by the test to sample the explosion debris.

The basic elements which could be addressed in joint discussions include the fundamental science of the transmission of seismic waves within the Soviet Union; the types of equipment which would need to be permanently installed for the measurement of seismic data; the equipment which would need to be installed for the recording and transmission of seismic data to national data analysis centers; and the numerical data-processing techniques which would be used for identifying the source of a seismic event based on the characteristics of the seismic data. These issues are described in more detail below:

- *Seismic Wave Transmission:* The United States is actively pursuing the seismic research which would be critical to the detection and identification of low-yield (below 10 kt) nuclear tests. Of particular significance is research on high-frequency seismic waves. Instruments capable of detecting high-frequency seismic waves have been developed and an experimental seismic array containing such equipment is in operation. To be confident that high-frequency seismic waves can be useful for detection and identification of low-yield nuclear tests, two issues need further study: the availability of sufficiently quiet, low background seismic noise sites within the Soviet Union at which seismic stations could be located and knowledge of the transmission characteristics of high-frequency seismic waves within the Soviet Union.

  The degree to which seismic wave energy is absorbed and scattered as a seismic wave travels away from a nuclear explosion in the United States has been studied extensively, and much of this work has been published in the scientific literature. Similar information is not available for explosions within the Soviet Union. A joint U.S.-Soviet effort could seek to determine the degree to which high-frequency seismic wave energy is absorbed and scattered in the Soviet Union. Such an effort would establish a more realistic basis for the utility of high-frequency seismic waves for detection and identification of low-yield nuclear tests. While data obtained from outside the Soviet Union are useful, Soviet-U.S. cooperation in obtaining and evaluating data from within the Soviet Union is essential.

- *Seismic Equipment and Data Handling:* During the trilateral CTB negotiations of 1977-80, the United States described to the Soviet Union tamper-proof, remotely operated seismic stations which would record and transmit seismic data for analysis in the United States. The United States has continued research on such stations. Modification in these stations would be required to provide the capability to record and transmit data on high-frequency seismic waves. Joint Soviet-U.S. efforts could resume on the criteria for the location and operation of such stations to include characterization of the sites which would have to be available to ensure accurate instrument operation. Such an effort would have to include data gathering from potential sites for remote stations in the Soviet Union and should include installation of research instruments to validate that such instruments can operate reliably, to include data transmission, throughout the broad range of environmental conditions within the Soviet Union.

- *Seismic Wave Analysis:* The effectiveness of any low-yield underground nuclear test verification regime based upon the analysis of seismic waves will ultimately depend on the ability to identify a nuclear explosion by distinguishing between nuclear explosions and other sources of seismic energy, e.g., chemical explosions and earthquakes. The object must be to minimize the number of recorded seismic events whose source is ambiguous. A joint Soviet-U.S. effort could seek to identify analytic techniques which would positively identify the origin of recorded seismic signals. Such a joint study cannot be done in the abstract but should be tested against real data which would be typical of that which would be recorded by instruments located at the prospective location of seismic stations. No analytic technique can hope to eliminate all ambiguous events, but it would be very helpful if the two sides could agree on which technique can be the most effective.

V. Current Status

We have sought on a number of occasions in the past several years to engage the U.S.S.R. in discussions on verification improvements in the nuclear testing area but thus far without success. In 1983 the U.S. Government sought on three separate occasions to engage the Soviet Union in a discussion of essential verification improvements for the TTBT and the PNET. In September 1984 the President proposed in his address to the UN General Assembly that the United States and the Soviet Union find a way for Soviet experts to come to the U.S. nuclear test site and for U.S. experts to go to theirs to measure directly the yields of nuclear weapons tests. In July 1985 the President expanded his offer with an unconditional invitation for Soviet experts to go to the U.S. nuclear test site to measure the yield of a U.S. nuclear test with any instrumentation devices they deemed necessary. There was no requirement for a reciprocal visit by U.S. experts to a Soviet test site. In December 1985 President Reagan proposed to General Secretary Gorbachev that U.S. and Soviet experts on nuclear testing limitations meet in February 1986 to discuss our respective verification approaches and to address initial tangible steps to resolve this issue.

Most recently, on March 15, 1986, the President urged the Soviet Union to join the United States in discussion on finding ways to reach agreement on essential verification improvement of the TTBT and PNET. In this respect he provided details to the Soviet Union on the U.S. CORRTEX hydrodynamic measurement system and proposed that General Secretary Gorbachev send Soviet scientists to our Nevada test site during the third week of April 1986 to fully examine CORRTEX. At that time, the Soviets could also monitor a U.S. nuclear test. Finally, the President indicated that, if the Soviet Union will join us in an agreement for effective verification, including the use of CORRTEX, the United States would be prepared to move forward on ratification of the TTBT.

The Soviets have stated that they have developed and have available a system that is used to obtain data similar to that obtained by CORRTEX. Aside from this assertion, the Soviet Union has not responded to any of the above U.S. initiatives, which were aimed at constructively addressing our mutual concerns. ■

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Policy Paper 5

Nuclear Weapons Testing

January 1987

U.S. Department of Energy

"While we are actively investigating technologies that may one day make us less dependent on offensive nuclear weapons for our security, nuclear weapons will remain for the foreseeable future the key element of our deterrent. In such a situation, where both the U.S. and our allies must rely upon nuclear weapons to deter aggression, nuclear testing will continue to be required."

President Reagan - letter to Non-Aligned Group of Six, March 12, 1986

"A comprehensive test ban remains a long term objective of the United States. We believe such a ban must be viewed in the context of a time when we do not need to depend on nuclear deterrence to ensure international security and stability and when we have achieved broad, deep and verifiable arms reductions, substantially improved verification capabilities, expanded confidence building measures, and greater balance in conventional forces."

President Reagan - letter to U.S. Allies, March 14, 1986

Overview - Why We Need Nuclear Tests

- Our security and that of the Free World depend on deterrence.
- For deterrence to work, potential aggressors must be convinced that we have the capability and the will to deliver a devastating response to attack on us or on our allies.
- U.S. nuclear weapons are an essential part of deterrence.
- Nuclear weapons must be tested to remain safe, reliable, effective, and survivable.

The Historical Role of Nuclear Weaponry

- Nuclear deterrence was established as a postwar counter to Soviet land armies.
    - No massive U.S. armies or large draft
    - Limited NATO commitments
- Deterrence has been successful in holding down U.S. defense expenditures.
    - 1955: Defense Budget = 11.2% of GNP

      Defense Budget = 62.4% of Federal Budget
    - 1985: Defense Budget = 6.6% of GNP

      Defense Budget = 26.5% of Federal Budget

The decision was made early in the postwar era that the United States and its European allies would not attempt to match the huge land armies of the Soviet Union. Nuclear weapons have been used to augment NATO forces, but their primary role has always been to deter Soviet attack. The strategy has been successful, and (for example) has let the U.S. keep the peace without relying on large armies or on a military draft for the last decade. Without conventional disarmament, weakening our nuclear deterrent could "make the world safe for conventional war."

Nuclear deterrence has also let the U.S. hold down its military expenditures. Contrary to the belief held by many, U.S. military spending as a fraction of gross national product is only about half as much today as during a similar period of peace and prosperity 30 years ago.

Nuclear Testing is Essential to U.S. Security

- It is essential to ensure stockpile reliability.
- It is essential to modernize our nuclear weapons systems in response to changing threats and to include the most modern safety and security devices.
- It is essential to ensure that our weapon systems are invulnerable to nuclear effects.
- It is essential to avoid technological surprise by an adversary.

Testing is required to ensure the safety and reliability of any complex system. We would not dream of flying in an airplane that had not been tested. Yet, some would ask us to have confidence in our nuclear weapons, some of the most complex mechanisms in existence today, without testing.

Here are four specific reasons why we need to test our nuclear weapons:

First, we need to test to maintain our confidence in the reliability of weapons that are in stockpile. In the past, there have been reliability problems where underground nuclear tests were necessary to find the problem and to confirm that the repair worked. Without nuclear testing, we would lose confidence in our deterrent.

Second, nuclear testing is essential for the development of safe, secure and effective warheads for the new weapons systems necessary to counter the changing Soviet threat.

Third, we need to conduct nuclear tests to ensure that our weapons systems can survive the nuclear effects of enemy nuclear warheads.

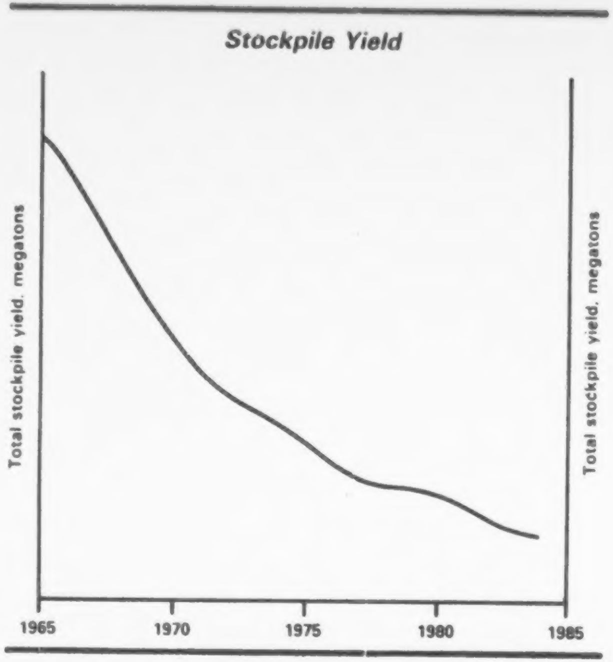
Finally, nuclear testing is essential to keep abreast of possible Soviet nuclear weapons developments and to avoid any technological surprises. We test neither more often nor at levels higher than necessary to meet our security requirements.

U.S. Depends on Testing More Than the Soviet Union

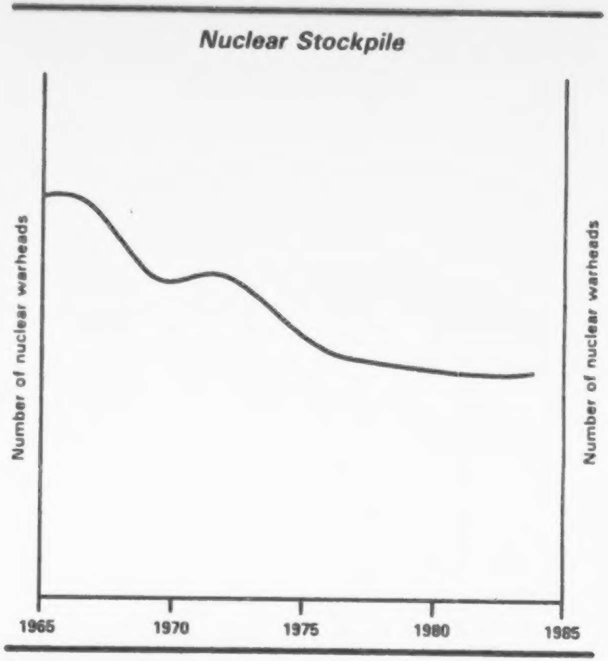
- U.S. warhead designs depend more on high technology.
- Lower U.S. missile throw-weight needs optimized warheads.
- U.S. demands higher safety and security standards than Soviets.

Nuclear testing is probably more important to the U.S. than to the Soviet Union. Based on available evidence, the U.S. relies more on high technology and on optimized warhead characteristics in our nuclear warhead designs. In a testing environment more limited than currently, Soviet missile throw-weight and volume advantages would allow the Soviets to more easily rely on previously tested, heavier, higher yield, simple warhead designs. Moreover, American standards of safety for nuclear weapons are almost certainly higher than those the Soviet Union imposes. These higher standards require more testing to verify that the implementation of them does not interfere with operation of the warheads. The U.S. goes to great lengths in warhead design to preclude not only unauthorized detonations, but also any dispersal of radioactive material in case of an accident. All of these goals, specific to the American value system, lead to a greater U.S. reliance on nuclear testing.

TESTING HAS ALLOWED REDUCTIONS IN THE U.S. STOCKPILE



Stockpile Yield



Nuclear Stockpile

Source: Presentation of Secretary of Defense Weinberger to Senate Armed Services Committee in *Hearings: Department of Defense Authorization for Appropriations for Fiscal Year 1985*, 1984, pt. 1, p. 123.

Contrary to the assertions of some, the U.S. nuclear weapons program, of which testing is but one part, has not led to an ever larger stockpile, with greater total destructive force. In no small measure, thanks to innovations and improvements made possible by testing, we have been able to introduce newer, safer and more effective systems while actually significantly reducing the number of weapons in our nuclear arsenal from what we had 20 years ago. The number of weapons in the U.S. nuclear stockpile was about one-third higher in 1967 than it is today. Moreover, our arsenal today has one quarter the explosive force we fielded two decades earlier.

Verification is Still a Problem

- Teleseismic detection and identification of low yield tests cannot be relied on.

- Soviets could test in underground cavities.

  — To try to conceal low yield tests

  — To interfere with seismic yield estimation

- Testing also could be done by the Soviets in deep space or remote areas of the world.

Seismic monitoring from remote stations — the only verification means currently available to us for monitoring underground testing — is not sufficiently sensitive to detect and identify small tests, much less to estimate their yields.

Detonating weapons in underground cavities "decouples" the blast from the surrounding earth and greatly complicates the verification problem. Sufficiently small tests might be totally undetectable, while larger ones would appear to have lower yield than is actually the case.

There is virtually no limit to the size of a test that could be concealed in very deep space, a strategy with little attraction today (when 150 kiloton tests can be done legally underground), but one which might have much more appeal in the presence of a comprehensive or low-yield threshold test ban.

It is true that substantial improvements have been made in verification technology. But many problems remain, as do the national security concerns that would make a test ban undesirable today, even in the presence of the very best verification.

Historical Experience with a Nuclear Test Moratorium

- The 1958-1961 moratorium demonstrates the dangers and unacceptability of such an approach.
    - Reliability problems, in some cases outright failures
    - The Soviet breakout

The U.S. does not believe that a testing moratorium is a prudent, effective, or constructive step toward our goal of a safer world. A look back at the 1958-61 testing moratorium demonstrates why the U.S. believes that moratoria are never acceptable substitutes for negotiated, equitable, and effectively verifiable arms control agreements. Certain warheads introduced during the moratorium were subsequently found to have design flaws that, if they had not been detected and corrected through testing, would have had catastrophic effects on our deterrent. And we should never forget that the Soviets used the time of the moratorium to design new atmospheric experiments and to develop a plan for their execution. Then they resumed testing with what is still today the most intensive series of nuclear tests in history. Because our technical base degraded sharply during those years without testing, it took us nearly a year and a tremendous effort to restore our previous capabilities. As President Kennedy warned at the time:

> *"Some may urge us to try it (a moratorium) again, keeping our preparations to test in a constant state of readiness. But in actual practice, particularly in a society of free choice, we cannot keep topflight scientists concentrating on the preparation of an experiment which may or may not take place on an uncertain date in the future. Nor can large technical laboratories be kept fully alert on a standby basis waiting for some other nation to break an agreement. This is not merely difficult or inconvenient — we have explored this alternative thoroughly, and found it impossible of execution."*

3/2/62 Address to the American People

A Test Ban At This Time - Not the Route to Peace

- A test ban is not arms control.
    - No reduction of existing nuclear arms
    - No reduction in the non-nuclear threat
- A test ban could lead to instability.
    - Weakens this country's deterrence
    - Can tempt the other side into aggression
- Weakened deterrence is a threat to world peace.

A nuclear test ban is not arms control, nor is it a step in the direction of any arms limitation that would enhance the safety of this or other countries. Not one of the nuclear, chemical, or conventional weapons that threaten us today would be eliminated by a test ban. Rather, a test ban would simply deny this country the ability to maintain and modernize its nuclear forces. Loss of that ability would undermine the deterrence on which the security of the Western World depends; it would be a form of unilateral disarmament.

This erosion of American strength could have the effect of tempting enemies, currently deterred by our nuclear forces, to threaten Western security through direct coercion, or indirectly through continued encroachment such as has occurred in Afghanistan. Thus, contrary to the arguments of its proponents, a nuclear test ban at the present time would not serve the cause of peace. In reality, it might even be a threat to peace.

Some Frequently Asked Questions

The Soviet Union Stopped Nuclear Testing For Over A Year. Why Can't We?

Continued nuclear testing is essential to the maintenance of our nuclear deterrent, which is the ultimate guarantor of U.S. and allied security. While we conduct nuclear testing neither more frequently nor at yields higher than absolutely necessary to meet our security needs, our decisions must be based on those needs and not on the actions that may or may not be taken by another country.

In fact, nuclear testing appears to be more important to the U.S. than to the Soviet Union. American standards of safety for nuclear weapons are almost certainly higher than those required by the Soviets. Differences in our force structure also contribute to our assessment that the U.S. relies more on high technology and optimized warhead characteristics than do the Soviets; in a no-test environment, for example, the Soviet missile throw-weight and volume advantages could permit them to fall back on previously tested, heavier, and relatively simpler warhead designs. Moreover, in a no-test environment leading to the erosion of the credibility of the U.S. nuclear deterrent, Soviet advantages in conventional and chemical forces unrestrained by any testing limitation would be magnified — with a resultant deterioration of Western security.

Will We Have To Keep On Testing Nuclear Weapons Indefinitely?

A comprehensive test ban remains a long-term objective of the United States. While we are actively investigating technologies that could one day reduce and ultimately eliminate our dependence on nuclear arms for our security, nuclear weapons will remain the key element of deterrence for the foreseeable future. During such a period, where both the United States and our friends and allies must rely upon nuclear weapons to deter aggression, nuclear testing will continue to be required.

Don't We Already Have More Weapons Than We Need For Deterrence?

The ultimate U.S. long-term objective is the eventual complete elimination of nuclear weapons. As a step in that direction, we are negotiating with the Soviet Union in Geneva for substantial, stabilizing and verifiable reductions in both strategic and intermediate-range nuclear forces, and we hope the Soviet Union will negotiate seriously toward this objective.

At the same time, it is important that we maintain an adequate nuclear deterrent. Many of our current nuclear weapons are aging and becoming increasingly vulnerable as a result of the massive Soviet buildup and relative U.S. restraint during the last 15 years. Our objective, embodied in the President's strategic modernization program, is not to increase the number of weapons, but to replace aging weapon systems with newer ones that can continue to deter effectively. If we do not take these steps to modernize now, the Soviet Union will have little incentive to negotiate for the significant reductions we are proposing in Geneva.

Can't Supercomputers Do The Analysis That Makes It Unnecessary To Test?

No. A nuclear explosion is an extraordinarily complicated physical process, and one which is not fully understood even by the most expert scientists. The complexity of the physical processes involved requires that we make many approximations in the calculations. It is true that our scientists rely on and use supercomputers heavily in the design process. However, even with all that capability, we have frequently found significant differences between computer predictions and the actual results of nuclear tests. Deterrence requires that we pose a credible retaliatory capability to any prospective adversary — i.e., a capability requiring real, effective weapons, based on careful computer design and adequate nuclear tests.

Wouldn't A Test Ban Slow The Soviet Union Down Just As Much As Us?

The U.S. and the Soviets have different target sets: the Soviets have invested heavily in hardening their targets, while we have not. To hold those important Soviet assets at risk without unacceptably high levels of collateral damage, we must optimize the yield-to-weight ratio of our warheads. Because of this, nuclear testing appears to be more important to the U.S. than to the Soviet Union. Based on available evidence, we think that we rely more on high technology and on optimized warhead characteristics in our nuclear warhead design than do the Soviets. In a no-test environment, Soviet missile throw-weight and volume advantages could permit the Soviets to fall back on previously tested, heavier, and relatively simpler warhead designs, which generally should be more reliable and rugged.

With Modern Technology, Can't We Keep Them From Cheating On A Test Ban?

No. We cannot even tell with certainty whether they are complying with the existing 150-kiloton limit on testing. If the limit were lowered, we could be sure only that the verification problems would be worse. Even small violations of a comprehensive or low yield threshold test ban could be very important if we ourselves were doing little or no testing. Furthermore, violations need not be so small. Testing at high yield, undetectably, in deep outer space is an option that makes little economic sense today; but it is a possibility that might be very attractive to the Soviet Union if a comprehensive or low-yield test ban were in place.

If We Stopped Testing And Found Ourselves Falling Behind Militarily, Couldn't We Just Start Up Again?

Not without great difficulty and delay. An example of this kind of expectation is our experience at the end of the 1958-61 informal moratorium when the Soviets resumed testing with what is still today the most intensive series of nuclear tests in history. Because our technical base degraded sharply during those years without testing, it took us nearly a year and an extraordinary effort to restore our previous capability to perform militarily significant nuclear tests. The effect of a long-term comprehensive test ban would be much more severe. In our country, in contrast to the practice in the Soviet Union, nuclear weapons scientists could move into more promising careers; test facilities would fall into disrepair; annual appropriations would be committed to other programs. President Kennedy in 1962 recognized that this option "is not merely difficult or inconvenient — we have explored this alternative thoroughly, and found it impossible of execution."

Why Are The Soviets Pushing So Hard For A Test Ban?

We are under no illusions as to the purpose that the Soviet authorities hope their test ban campaign will serve: to confuse further the domestic debate about the need for American nuclear testing. The Soviets also would have much to gain from a test ban:

— Differences in our force structure and weapons characteristics make the Soviets less dependent on testing.

— We have much more stringent safety and security standards than the Soviets, and hence need more tests to ensure that these standards do not lead to inoperable weapons.

— The U.S. respects its international commitments; the Soviets have the capability, motive, and demonstrated willingness to violate such obligations, including agreed limitations on nuclear testing, thus gaining unilateral advantages.

— Even if our confidence in our respective nuclear forces were to erode in a similar fashion — and this is very unlikely — Soviet advantages in conventional and chemical forces would lead to a net deterioration of Western security.

How Much Could The Yield Limits Of Nuclear Tests Be Reduced Without Significantly Hurting Our Weapons Program?

The U.S. tests neither more frequently nor at levels higher than is absolutely necessary to meet our security requirements. We must retain the flexibility to adjust our testing to respond to changes in the Soviet threat and to ensure that our weapons remain safe and effective.

There is no "magic" yield level above which tests are not needed. With today's 150-kiloton limit, we have already restricted our program considerably: we can no longer conduct tests of most strategic weapons at full yield. To some extent, weapon performance can be extrapolated from partial-yield tests, but as the range of extrapolation increases, our confidence in weapon performance decreases.

Only by testing at yields up to 150 kilotons are we able to validate performance of the fusion stage of many strategic weapons. As threshold levels decrease, it eventually becomes impossible even to test the fission or "trigger" stages. Nuclear effects tests (to study and overcome vulnerabilities to enemy countermeasures) and weapon physics tests may range from less than a kiloton to many kilotons, depending on the particular phenomena being studied. We believe that the reduced confidence in our nuclear deterrent which would result from the elimination of such necessary testing would be unacceptable.

Wouldn't A Test Ban At Least Be A Step In The Direction Of Meaningful Arms Control?

Our priority is and must remain the goal of deep, equitable, and effectively verifiable reductions in Soviet and American nuclear weapons. A test ban would be inequitable, undesirable, and unverifiable, and would not reduce existing arsenals by a single weapon. Indeed, a test ban might well lead to an increase in force levels as confidence is lost in the existing stockpile. In short, a test ban would set back, not help, our efforts to achieve real reductions.

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Reagan Plan on Verifying Nuclear Tests Faulted

NYT 1-13-87

Intelligence officials propose far broader approach.

By MICHAEL R. GORDON

Special to The New York Times

WASHINGTON, Jan. 12 — Government intelligence officials say a far more comprehensive approach should be taken to verifying Soviet and American compliance with limits on nuclear testing than has been proposed by the Reagan Administration, according to newly-obtained secret documents.

The intelligence officials say the Reagan Administration's proposal is technically flawed.

The Administration proposal to the Soviet Union for verifying compliance with two unratified 1970's treaties, which limit the size of underground explosions, is "deficient" and fails to "meet the tests of comprehensiveness and technical soundness," according to a classified memorandum dated Dec. 4. The memorandum was prepared by a Central Intelligence Agency official, who was speaking on behalf of the Government's entire intelligence apparatus.

Another C.I.A. official noted in a classified memorandum dated Dec. 13 that the Administration proposal contained "inconsistencies, contradictions and incomplete work" that would not escape close scrutiny by Congress. "Frankly, if the Soviets had said 'yes' to our initial proposals, we would be in trouble," he wrote.

The intelligence experts propose what the Dec. 4 memorandum calls a "rich package" of methods to expand the Administration's plan of on-site measures of the size of Soviet tests. The intelligence experts' package includes these key elements:

¶Initial inspection of Soviet testing sites to confirm Soviet information on the geophysical characteristics of the sites.

¶The detonation of American chemical devices at Soviet testing sites to check the accuracy of seismic detection systems.

¶The establishment of monitoring stations on Soviet territory. Such stations, which could be staffed by international teams, had been proposed by Argentina, Mexico, Tanzania, India,

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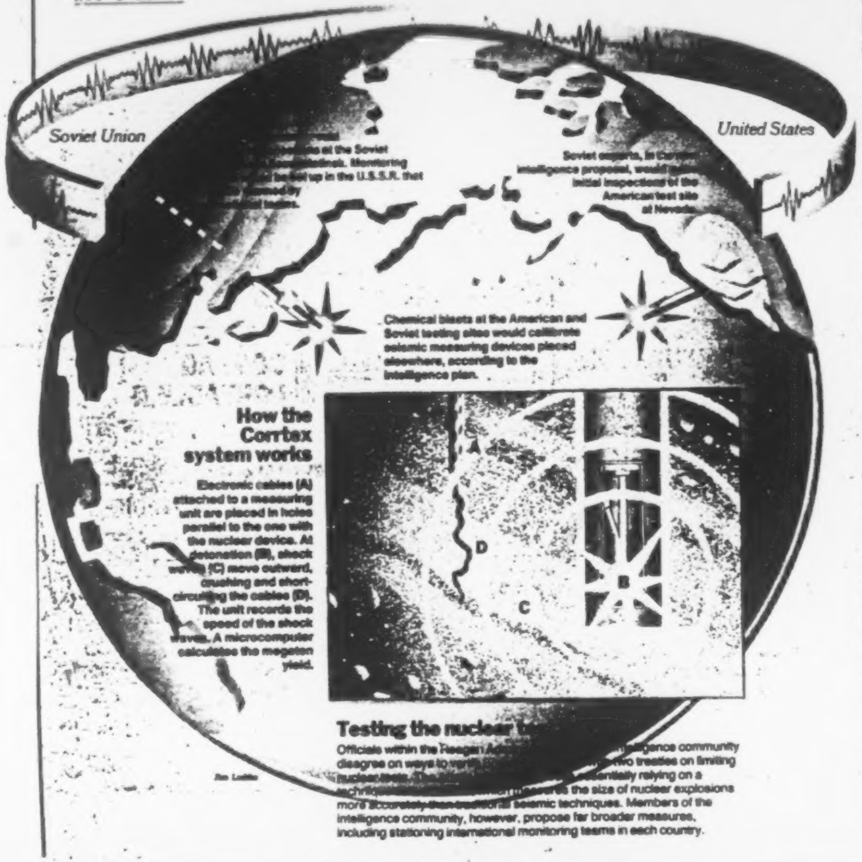


[illegible] at the Soviet [illegible]. Monitoring [illegible] be set up in the U.S.S.R. that [illegible]

Soviet experts, in [illegible] intelligence proposal, would [illegible] initial inspections of the American test site at Nevada.

Chemical blasts at the American and Soviet testing sites would calibrate seismic measuring devices placed elsewhere, according to the intelligence plan.

How the Corrtex system works

Electronic cables (A) attached to a measuring unit are placed in holes parallel to the one with the nuclear device. At detonation (B), shock waves (C) move outward, crushing and short-circuiting the cables (D). The unit records the speed of the shock waves. A microcomputer calculates the megaton yield.

Testing the nuclear t[illegible]

Officials within the Reagan A[illegible] intelligence community disagree on ways to verify [illegible] two treaties on limiting nuclear tests. [illegible] essentially relying on a technique [illegible] the size of nuclear explosions more accurately than traditional seismic techniques. Members of the intelligence community, however, propose far broader measures, including stationing international monitoring teams in each country.

Reagan Plan on Verifying Nuclear Tests Faulted

Continued From Page C1

Sweden and Greece for the monitoring of a total test ban, the classified Dec. 4 memorandum notes.

¶The requirement of additional sharing of information between the countries when ambiguities in data arise.

The criticism by the intelligence experts has sparked a wide-ranging philosophical and technical debate within the Government. The debate raises the question of about how effectively the Administration has transformed its strong public commitment to verification into Government policy.

And the debate has important significance for future American negotiations with the Soviet Union on the testing issue. On the one hand, if the United States insists on monitoring procedures for the 1970's treaties that are too far-reaching, the Soviet may balk. This, in turn, could dim the prospects for future agreements on testing.

On the other hand, if an agreement can be reached on a broad range of new measures such as those proposed by the intelligence experts, it could provide a technical basis for negotiating lower limits on the size of nuclear explosions in the future.

The treaties in question are the Threshold Test Ban Treaty of 1974, which limits underground explosions to 150 kilotons, and the Peaceful Nuclear Explosions Treaty of 1976, which extends this limit to detonations used for engineering purposes.

On the eve of the Iceland summit meeting last year, President Reagan sent a letter to Congress saying he would make Senate approval of the treaties "a first order of business" this year with the caveat that the treaties would not take effect until new measures are employed to make them "effectively verifiable."

Mr. Reagan also said that as soon as the United States and the Soviet Union agreed on such measures, the two countries would begin a new set of talks to set additional limits on nuclear tests.

Administration officials are scheduled to testify on the 1970's treaties before the Senate Foreign Relations Committee Tuesday.

The technical debate centers on the relative merit of two techniques for monitoring nuclear explosions: Corrtex and seismic monitoring.

Corrtex, which stands for Continuous Reflectometry for Radius versus Time Experiments, is at the heart of the proposals presented in Geneva last year to the Soviet Union by the Reagan Administration.

Corrtex takes direct measurements of nuclear detonations through a cable inserted into the ground close to the blast. Electrical pulses are transmitted to the end of the cable and back. When the nuclear device explodes, the shock wave crushes and shortens the cable, and scientists determine from the electrical pulses how quickly the cable is shortened. This is used to determine how fast the shock wave moves through the ground and, by inference, how large the blast is.

The technique requires that American officials go to the Soviet test site to install and monitor the equipment.

The other approach, the use of seismic monitoring, is stressed in the more comprehensive approach outlined by the intelligence experts. It involves assessing the size of a nuclear blast by measuring different types of seismic waves that travel through the earth.

Experts say there are three basic types of such waves: body waves, which travel deep through the earth's interior; surface waves, which travel far distances in the earth's upper layers, and Lg waves, which travel in the upper 50 kilometers of the earth but do not travel for great distances. Independent measurements of these waves and other geological data can be used to improve the accuracy of seismic reading.

¶ It is generally acknowledged that the United States' current ability, primarily seismic, for monitoring the treaties involves uncertainties.

One uncertainty stems from the differing geology of the test sites in the United States and in the Soviet Union. Experts say the Soviet test area at Semipalatinsk has been geologically stable for hundreds of millions of years, while there has been volcanic activity at the American test site in Nevada within the last few million years. Because of these differences, a Soviet test explosion produces a larger discernible wave traveling through the earth's interior than an American blast of the same magnitude. Seismologists have tried to compensate for this bias by introducing a corrective factor into their calculations.

Another monitoring uncertainty is that seismic measures are not exact. The Administration asserts that seismic measures are accurate to a factor of about two -- that is, according to the Administration, an explosion of 100 kilotons could be measured as twice as large, 200 kilotons, or as half as large, 50 kilotons, though statistically most of the measurements would be concentrated in the middle. Some seismologists believe the uncertainty is not as great as the Administration says and can be reduced through new seismic techniques. Corrtex measurements of tests that are more than 50 kilotons have an uncertainty factor of about 1.3, the Administration says.

One key question is whether these uncertainties are manageable or whether new measurement techniques are needed.

Some experts believe that the treaties can be adequately verified without new techniques. Representative Dave McCurdy, Democrat of Oklahoma, a senior member of the House Permanent Select Committee on Intelligence, maintains that, given the United States' current monitoring abilities, the Soviet Union could not exceed the treaty limits in a way that would give it a military advantage, according to a McCurdy aide.

And Spurgeon M. Keeny Jr., a former deputy director of the Arms Control and Disarmament Agency, said the Administration's demand for additional verification for the treaties could set a "bad precedent" of asking for instrusive verification that is not really needed.

Supporters of this view also say verification of the treaties could be improved if the United States would simply ratify them and allow them to go into effect. The treaties provide for an exchange of information on geology and the size of a test explosion, but the Reagan Administration says it would have no way to confirm such information and has refused to ratify the agreements.

Some Administration experts say a limited use of Corrtex would suffice to improve verification. The Corrtex technique would be used, according to this view, to check the accuracy of seismic readings and "calibrate" American seismic monitoring systems outside of the Soviet Union.

But the Administration has proposed a more far-reaching use of Corrtex. It has asked that it be used on each Soviet blast of 75 kilotons or more so as to compensate for the uncertainty of seismic readings and to insure that the blast is not over the 150-kiloton limit. If the Soviet Union does not conduct a test this large over a six-month period, the Administration would monitor the largest test conducted. A kiloton is equivalent to the explosive force of a thousand tons of TNT.

Officials from the Arms Control and Disarmament Agency have been drafting a new protocol to the treaties based on this Administration approach.

But the view now being presented by Government intelligence experts represents a new variable in the verification debate.

According to classified Government documents, the intelligence experts argue for a far more comprehensive approach that would include several "mutually reinforcing elements." The experts have argued that additional measures are needed to insure that when the monitoring is in force the Soviet Union is, in fact, notifying the United States of all tests that are 75 kilotons or greater.

In addition, they say that the Soviet has shown a receptivity to some of the new measures in the context of a ban on all nuclear tests and that the United States should try to take advantage of this in the context of limiting test size.

Some seismologists have previously argued that some of the measures suggested by the intelligence experts to improve the monitoring of the treaties would be particularly useful for monitoring any new agreements with much lower limits on the size of underground detonations.

Paul G. Richards of Columbia University's Lamont-Doherty Geological Observatory told the House Permanent Select Committee on Intelligence last year that in-country monitoring stations could be used to detect Lg waves, the regional seismic waves that do not travel long distances.

By analyzing these waves, along with other types of seismic waves monitored from outside the Soviet Union, experts can substantially reduce the uncertainty surrounding seismic reading. Mr. Richards suggests that a factor of 1.5 uncertainty can eventually be achieved, close to the 1.3 factor currently claimed for Corrtex.

Charles B. Archambeau of the Univesity of Colorado has also suggested that the explosion of chemical devices near Soviet test sites, as the intelligence experts propose, would be a useful way to learn about the geology of areas. This, he says, would help improve the accuracy of seismic measurements. Mr. Archambeau has worked with the Natural Resources Defense Council, a private group that is working with the Soviet Academy of Sciences on private seismic monitoring stations in the Soviet Union and the United States.

Some experts say the Government intelligence experts are right to seek a broader approach that does not focus exclusively on Corrtex.

For one thing, they assert, th Soviet would not be likely to accep the extensive use of Corrtex as proposed by the Administration becaus it would require an almost constan American presence at the test site.

In addition, they say Corrtex is no a useful technique for measuring explosions of less than 50 kilotons an that the Administration's exclusiv reliance on it may reflect an underlying hostility to negotiating substantially lower limits on the size of tests. They say the new seismic monitoring measures could monitor small tests.

But some Government officials are sharply critical of the comprehensive approach. These opponents say, for instance, that the intelligence experts may be interested in gathering intelligence information that is not necessary to monitor treaty compliance.

Another objection is that some of the proposals by the intelligence experts, such as in-country monitoring stations, are more appropriate for monitoring a low limit on explosion size or a moratorium on tests than for the monitoring the 1970's treaties. The critics also maintain that the use of chemical detonations would introduce new complications, such as the need to determine how much they replicate the effects of a nuclear blast.

Another philosophical difference pertains to how important it is to determine conclusively whether the Soviet Union is properly notifying the United States of all tests of 75 kilotons or more. Critics of the comprehensive approach say the main goal of verification is to confirm that Soviet tests do not exceed 150 kilotons and that intelligence experts are losing sight of that objective in suggesting that the United States needs to be absolutely sure that it has been informed of all Soviet tests that are 75 kilotons or more.

Government officials said the current verification debate within the Administration will probably not be resolved anytime soon. The current plan, they say, is to present the treaty protocol and the intelligence community's reservations to the National Security Council and let the White House decide the question.

24 Soviet Violations of the Threshold Test Ban Treaty

by
US Senator James A. McClure
January 15, 1987

The attached Defense Department chart indicates clearly that the Soviet Union has violated the 150 kiloton threshold on underground nuclear weapons testing of the Threshold Test Ban Treaty (TTBT.)

Soviet Legal Obligation

Even though the TTBT, signed in July, 1974, has not been ratified on either the US or the Soviet side, under international law both the US and the USSR are required to do nothing which would defeat its object and purpose, during the period when ratification is still pending. Moreover, in March, 1976, by US-Soviet mutual agreement the 150 kiloton threshold was put into effect as binding on each side. The Soviets have a clear legal obligation to comply with the 150 kiloton threshold. Thus even one Soviet test exceeding the 150 kiloton threshold would defeat the object and purpose of the TTBT, would violate it, and would be militarily irreversible.

The Soviet TTBT Violations

Both this chart and this analysis, which have recently been updated, are unclassified, according to the Department of Defense and the Arms Control and Disarmament Agency. This is the most complete unclassified description of the official US Government verification assessment of Soviet TTBT violations. It was published in the *Congressional Record* and in another official US Senate document.

My distinguished colleague, Senator Jesse Helms, requested that the earlier version of this chart be briefed to the Senate Foreign Relations Committee in open session in October, 1983, when the Committee was at that time considering whether to report out the TTBT to the full Senate. After this briefing, the motion to report the TTBT to the Senate Floor was defeated.

The chart shows that there have been 24 Soviet underground nuclear weapons tests since 1978 which are estimated to be above the 150 kiloton threshold, and therefore are violations of the TTBT. There is 95 percent confidence that several Soviet TTBT violations have occurred. Ten Soviet tests reportedly have been at 250 kilotons or above.

In June, 1983, Secretary of State Shultz testified to the Senate Foreign Relations Committee that the Soviets had recently tested a nuclear weapon about "double" the 150 kiloton threshold--at about 300 kilotons. The Defense Department chart indicates that since 1978, the Soviet Union has conducted 6 tests at the 300 kiloton level or higher--at a yield twice that allowed by the TTBT.

Indeed, one Soviet test was reportedly estimated to be over 315 kilotons, and it could have been over 600 kilotons. There is 100 percent confidence, which means certainty, that this test was a TTBT violation.

US Methodology Changes Give Soviets Benefits of Every Doubt

The US has for 12 years given the Soviet Union the benefit of every doubt or uncertainty in TTBT compliance. We have even gone so far as to change our estimating methodolgy four times since 1974, each time to favor the Soviets by reducing our estimates of their test yields, thereby making their violations under the previous method disappear. Despite this elasticity in US methodology, the Soviets have nevertheless continued to violate the TTBT. This chart shows only one methodology change, which occurred in early July 1977 and which was the most important, and the analysis describes a recent attempt to make a fifth change in Soviet favor.

The Chart's Vertical Axis

The vertical axis of the chart is labeled "The Sliding Rulers," showing how the US changed its methodology in early July 1977 to favor the Soviets by making 2 violations disappear. The vertical axis measures "Body Waves" (Mb) from Soviet underground nuclear weapons tests at Shagan River (Semipalatinsk), in Central Asia. Body Waves are seismic shock waves which travel on a constant path through the earth's core. This axis is basically a Richter scale.

The Chart's Horizontal Axis

The horizontal axis is time--March 1976, when the TTBT 150 kiloton threshold went into effect, through 1985. The key point in time is late July 1977, when the Senate Foreign Relations Committee first had hearings on the TTBT. The most important methodology change occurred in early July 1977, in order to make 2 Soviet TTBT violations disappear before the hearings began.

The Horizontal Bands Are 150 KT Thresholds

The horizontal bands represent US estimates of 150 kiloton thresholds, based upon various assumptions about the geological characteristics of the Soviet and US testing sites. The upper two bands represent Soviet 150 kiloton thresholds. The center band was the US-estmated Soviet 150 kiloton threshold until 2 Soviet violations began to appear in late 1976 and early 1977. The top band was the new Soviet 150 kiloton threshold, revised upwards in early July 1977 by the US to benefit the Soviets by making the 2 violations disappear. The higher band allows the Soviets ever larger test yields. This band is still the current Soviet threshold using our established methodology. The lowest band is provided merely to illustrate another benefit of the doubt resolved in Soviet favor. It is the US 150 kiloton threshold. It is based upon the known geological characteristics of the US Nevada Test Site. We have allowed the Soviets progressively higher thresholds by making progressively more generous assumptions about the geological characteristics of the Soviet Shagan River-Semipalatinsk test site.

The Soviet Nuclear Test Plots

Each black dot on the chart represents a Soviet underground nuclear weapon test at Shagan-Semipalatinsk. This unclassified data was provided by the US National Earthquake Information Service, expressed in Body Waves. (Not all Soviet tests are plotted, in order to avoid cluttering the chart.)

The Early July 1977 Methodology Change

Note that according to the Pre-July 1977 Soviet 150 Kiloton Threshold band, there had been two Soviet tests higher than this threshold in late 1976-early 1977. These 2 Soviet violations necessitated the changed estimative methodolgy resulting in the raising of the threshold to the Post-July 1977 Soviet 150 Kiloton Threshold. Accordingly, after raising the threshold in Soviet favor to make these 2 violations disappear in early July, the CIA was then able to testify to the Senate Foreign Relations Committee later in July and August, 1977 that there had been no Soviet violations of the TTBT 150 kiloton threshold.

But in late 1978 and 1979, the Soviets again began exceeding even this raised threshold. Moreover, their new excesses were very large.

The Dotted Line--Doubling of Soviet Yields

The dotted line on the chart differentiates tests which have twice the yield of each other. Tests above the dotted line are about twice the yield of tests below the dotted line. Because there are no anomalies except magnitude among Body Waves traveling along the same path through the earth's core, we know with high certainty that tests above the dotted line are twice the yield of tests below the dotted line. This relationship is sound, even though we have uncertainties about the absolute yields of tests.

Thus according to the dotted line, the Soviets doubled the yield of some of their tests in 1979 and thereafter, as compared to 1977. Therefore, if the two highest yields in the 1976-early 1977 period are now estimated to be about 150 kilotons in order for them to be in compliance with the TTBT, then the tests along the dotted line in 1979 and later have to be about 300 kilotons or more, twice the allowed yield.

No credence should be placed in the hypothesis that the Soviets may have cautiously tested at only one half the allowed yield, or at 75 kilotons, between July 1974, when the TTBT was signed, and March 1976, when the 150 kiloton threshold was mutually put into effect. This is because the US itself tested 12 times above 150 kilotons during this period, and the Soviets almost certainly knew this. Moreover, Soviet arms control compliance behavior has always been to exploit all loopholes to their fullest, and to go to the limits of allowed activities and beyond. They have never shown such presumed caution.

CIA Attempting New Methodolgy Change To Again Cover-Up Soviet Violations

Just as the CIA made the 2 1976-early 1977 Soviet violations disappear by raising the Soviet threshold in early July 1977, the CIA is reportedly once again trying to make Soviet TTBT violations disappear. The CIA has reportedly been using a new estimative methodology since January 1986 which makes all but the 12 highest Soviet high yield tests disappear as violations, once again trying to raise the threshold in Soviet favor, for a fifth time.

Reaffirmation of Presidential Findings of TTBT Violations

But the new CIA methodology is inconsistent with other established methodologies and is not accepted by a majority of the Executive Branch components. The early July 1977 methodolgy remains the current one. While additional studies have been undertaken, their conclusions are incomplete and have not been agreed upon. President Reagan's February and December 1985 Reports to Congress that there have been 21 to 24 Soviet underground nuclear weapons tests which are likely to have violated the 150 kiloton limit of the TTBT have been reaffirmed.

All-Source Evidence Confirms Soviet TTBT Violations

Soviet TTBT compliance is not solely a technical problem of analysis of teleseismic data. It is an all-source intelligence and verification problem. Far too much attention has been focused over the years upon the narrowly technical teleseismic evidence of Soviet tests. But other, non-seismic evidence and verification judgments about this evidence may be even more important. For example, one method using direct evidence from non-seismic National Technical Means of verification strongly supports the conclusion that there have been multiple Soviet TTBT violations at high yields. Another example is reported Soviet attempts to deceive US National Technical Means of TTBT verification into underestimating Soviet yields. This phenomenon also offers persuasive evidence of Soviet violations. Finally, even despite Soviet efforts at deception, on two widely separate occaisions the Soviets have reportedly made statements which had the effect of confirming their violations, both as to yield magnitude and number of violations. This diplomatic evidence is the most persuasive.

Military Significance of Soviet TTBT Violations

Why are the Soviets violating the TTBT? They have good reasons. The TTBT 150 kiloton threshold is militarily significant because it restricts testing the full yields and reliability of new Soviet MIRV warheads which could be used for a first strike capability. According to open sources, most new Soviet ICBM MIRV warheads are estimated to have yields in the 200 to 600 kiloton range. The ten Soviet tests over 250 kilotons therefore could have been scaled or even half yield tests of new warheads for the new 5th and 6th generation Soviet MIRVed ICBMs, such as the SS-24 and SS-X-26 follow-on for the SS-18, both of which are reportedly now being deployed.

The SS-X-26, in flight testing since Spring 1986, before SALT II dissolved, was reportedly recently successfully flight tested. SS-18 silos for it are already reportedly being converted. SALT II had an absolute ceiling on SS-18 follow-on ICBM Throw-Weight. The SS-X-26 follow-on to the SS-18 has even more Throw-Weight than the SS-18. The SS-X-26 reportedly will therefore carry even more warheads than the 14 carried on the super heavy SS-18, already in violation of SALT II. There may even have been several full yield tests at 500 or 600 kilotons of these new MIRV warheads for the new Soviet ICBMs.

In contrast, the US was severely handicapped in designing and testing warheads for the MX, Trident II, and ALCM by strict compliance with the 150 kiloton threshold. These warheads reportedly have never been tested for reliability at their full yields.

Ratification of TTBT-PNET is Appeasement

In sum, it would be an unprecedented exercise in appeasement of the Soviet Union for the US Senate to give its advice and consent for the President to ratify a TTBT which the Soviets are likely to be violating.

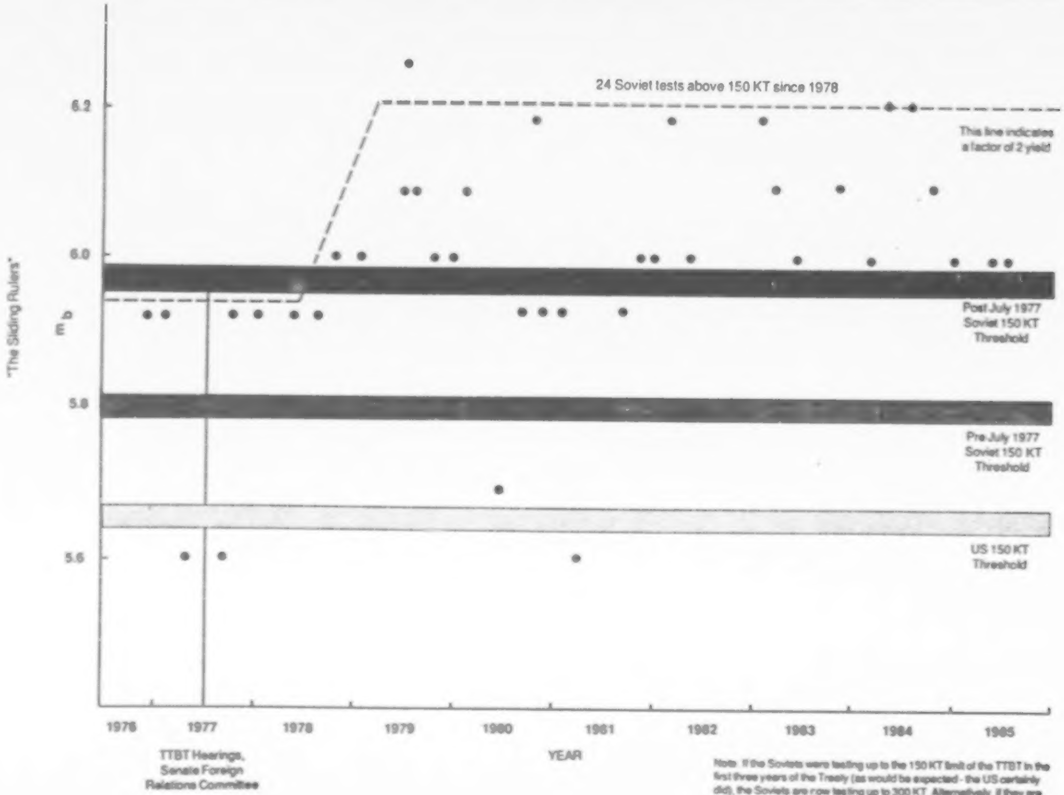
Moreover, the TTBT is integrally linked to its companion treaty, the Peaceful Nuclear Explosions Treaty (PNET.) The PNET preamble contains language that the US and the USSR reaffirm "their adherance" to the 1963 Limited Test Ban Treaty (LTBT), and they reaffirm "their determination to observe strictly the provisions of these [TTBT and LTBT] international agreements." Beyond his reports of Soviet TTBT violations, President Reagan also reported in February and again in December 1985 that there have been over 30 unambiguous, conclusively confirmed cases of Soviet venting of nuclear radioactive debris beyond their borders from underground nuclear weapons tests, in clear violation of the 1963 Limited Test Ban Treaty. Indeed, reportedly over 50 percent of all Soviet underground nuclear weapons tests have either clearly, probably, or possibly vented radioactive debris beyond Soviet borders in violation of the LTBT.

Thus Senate advice and consent for Presidential ratification of the TTBT and PNET, with its false reaffirmation of Soviet compliance with the TTBT and LTBT, would be totally inconsistent with the likely violations of the TTBT and the conclusively known violations of the LTBT. Such Senate advice and consent would be completely hypocritical. It would also be a grave and dangerous act of American appeasement of the Soviet Union, completely undermining the integrity of the arms control process, and international stability and peace.

The TTBT has been verifiable since 1976. We have verified Soviet violations with high confidence. The problem is not verification, but enforcing Soviet compliance. While the CORRTEX method of direct yield measurement would be a more effective verification method, it will not be a panacea and even it would have uncertainties. Even if the Soviets agree to some form of CORRTEX on site direct measurement verification in the future, their past violations give them irreversible military advantages. These Soviet advantages can not be "grand fathered" away, made to disappear, or ignored.

Instead of asking for Senate advice and consent for his ratification of these two treaties, albeit with a reservation to be negotiated with the Soviets on more effective verification, President Reagan should withdraw these two treaties from the Senate so that he can completely renegotiate the verification and compliance provisions with the Soviets.

SOVIET NUCLEAR EXPLOSIONS (SHAGAN RIVER TEST AREA) GLOBAL MAGNITUDES (N.E.I.S.) VS TIME



Note: If the Soviets were testing up to the 150 KT limit of the TTBT in the first three years of the Treaty (as would be expected - the US certainly did), the Soviets are now testing up to 300 KT. Alternatively, if they are testing below 150 KT now, they must have restricted testing to below 75 KT during the first 2-1/2 years. This is an unrealistic assumption.

Response of Admiral Sylvester Foley to a question asked by Senator Pressler

Question. Can we get the geophysical characteristics of the sites from the CORRTEX system?

Answer. In responding to your question, we must distinguish between the CORRTEX methodology and the CORRTEX instrumentation itself.

The CORRTEX instrument is a compact, rugged, solid-state electronics package. The electronics generate a series of electrical signals and record the time required for the signals to make a round trip, down and back up, in a coaxial electrical cable. There is no geophysical information in the recorded data. There is only a series of time measurements.

In performing a yield measurement using CORRTEX, a "satellite" hole is drilled parallel to the "emplacement" hole which contains the nuclear explosive. We envision an on-site presence during the drilling of the satellite hole in order to obtain samples of the subsurface geology and relevant logging results. Geological data are needed for CORRTEX in order to ensure that the measurements are within our test and/or modeling experience and the accuracy of the measurement is maintained.

The information incidental to the use of CORRTEX will also make teleseismic measurements more useful. In monitoring the drilling process we will learn the depth of the alluvium, location of the water table at the site of each hole, and we will be able to verify our assumptions about the geological media beneath Soviet tests sites, all of which matter in interpreting seismic data. Finally the CORRTEX data coupled with teleseismic information on the same shot will help us resolve uncertainties in the "bias" that we should use for seismic data from Soviet nuclear events.

The enclosed brief monograph CORRTEX provides additional information on this subject and I request that it be included in the record.

U.S. Department of Energy
Nevada Operations Office

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

CORRTEX

A new measuring system, called CORRTEX, can improve U.S. confidence in treaty compliance and possibly ease the way to further cooperation with the Soviet Union on other arms control issues. The lack of effective methods for verifying the size of underground nuclear weapon tests has proved to be a stumbling block for ratification of two major, closely linked nuclear test agreements, the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET).

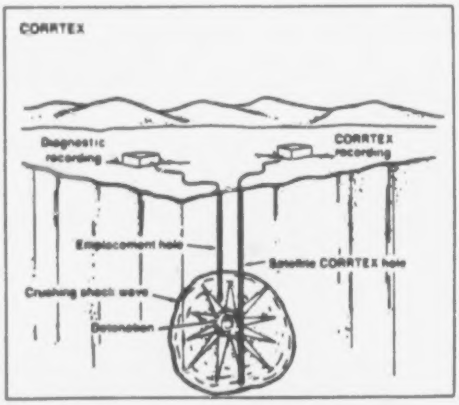
In March 1986, President Reagan proposed using CORRTEX to improve verification and ensure compliance with the TTBT, signed in 1974. This treaty limits explosive yields of underground nuclear weapon tests to not more than 150 kilotons. To date, verification of weapon testing limits has been based on remote monitoring, using a worldwide network of seismic stations that infer yields from the size of explosion-generated signals. The seismic procedure involves several assumptions about the local geology of test locations and about the modes by which signals travel to the seismic stations. An opportunity for relatively large inaccuracies in the yield determination is one result of these assumptions.

CORRTEX (an acronym for Continuous Reflectometry for Radius versus Time Experiments) is a fast, more accurate method for measuring yields of underground nuclear explosions and for ensuring compliance with the treaties. CORRTEX-type measurements have long been accepted as the technology of choice for verification of the PNET. But of foremost importance to the TTBT, CORRTEX also allows these measurements without revealing key weapon design information.

The CORRTEX system consists of a suitcase-size electronic unit, coaxial cables, and a microcomputer for data reduction. The electronics are so compact and rugged that they can be checked as ordinary airplane baggage and function properly after the abuses of travel. All equipment for power, recording, and data reduction can easily fit into a small trailer.

In use, the battery-powered electronic units remain above ground and can be remotely controlled. One or more coaxial electric cables attached to the units are inserted into holes extending from ground level to a point near the nuclear explosive. Repetitive electrical pulses are sent down the cable at intervals of 10 to 90 millionths of a second. The pulses reflect from the end of the cable and return to their source. Each electronic unit can alternately pulse two sensing cables.

When the nuclear device explodes, the shock wave travels outward and progressively crushes the cable, producing a fast-moving short circuit. Electrical pulses sent from the surface down the cable encounter the short circuit and are reflected to the electronic unit. The



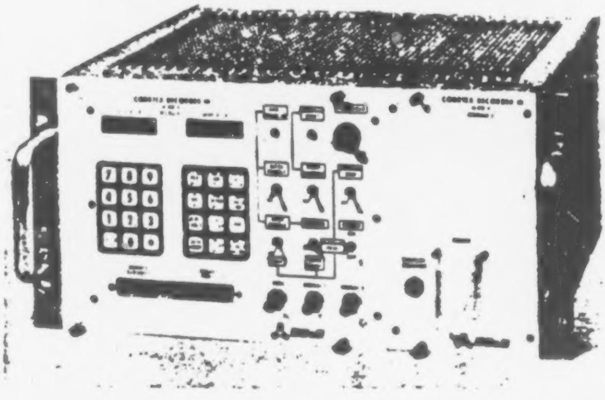
CORRTEX cables attached to an electronic unit are placed in separately drilled holes parallel to the hole containing the nuclear device and diagnostic equipment. When the detonation occurs, the resulting shock wave moves outward, crushing and short-circuiting the cables. The electronic unit on the surface records the progressive movement of the shock wave as a function of time. From these data, the microcomputer can calculate the yield of the explosion.

time required for the pulses to complete the round trip steadily diminishes and reveals the length of the cable—and therefore the location of the shock wave—as a function of time. More than 4,000 recorded data points cover the growth of the shock wave. A portable microcomputer then processes these data, to give the speed with which the electrical cable is shortened, and determines the yield of the explosion. Large explosions produce shock waves that travel faster than do those from small explosions. The microcomputer presents the recorded data in several forms, including graphics.

CORRTEX is based on ideas that go back to the early days of atmospheric testing when scientists determined the size of a nuclear explosion by measuring the supersonic growth of the shock wave in air (the fireball). With CORRTEX, scientists now measure the velocity of the supersonic shock wave in earth and determine the size of the underground explosion. Los Alamos National Laboratory, with the engineering support of EG&G, Inc., began development of CORRTEX as a verification tool for the PNET, signed in 1976. The PNET limits to 150 kilotons the yield of each nuclear explosion detonated for peaceful purposes, such as excavation, stimulation of fossil fuel reservoirs, or creation of underground cavities. Los Alamos now routinely uses CORRTEX to measure nuclear test yields at the Nevada Test Site.

Data from these nuclear tests at the Nevada Test Site indicate that, for tests larger than several tens of kilotons, CORRTEX is accurate to within 30% or better of the more direct and "standard" radiochemical yield measurements. This finding is based on many tests with the sensing cables both in the nuclear device emplacement holes and in nearby and parallel satellite holes. The accuracy of CORRTEX is known to be essentially independent of the surrounding geology, provided the measurement is performed in the "strong shock" region closest to the nuclear explosion. At greater distances from the explosion, the geology becomes more important. Placing the CORRTEX cables in a parallel satellite hole a few tens of feet from the emplacement hole appears best for ensuring that a test does not exceed 150 kilotons, while eliminating the opportunity to sense weapon design and diagnostic information.

The advantages of CORRTEX are many. CORRTEX is compact, rugged, simple in operation, fast, and the most accurate of the noninvasive techniques for measuring the yield of underground nuclear explosions.



The CORRTEX electronic unit is a rugged, suitcase-size instrument that can collect and store 4,000 data points per underground explosion.

Responses of H. Allen Holmes to Questions Asked by Senator Helms

Q. (Helms) It has been a decade since the TTBT and PNET were examined in depth by the Senate. Therefore, before we advise and consent to ratification, we should be satisfied that the treaties are not only verifiable, but that they are in the security interest of the United States. Please explain how the limits and obligations of the treaties, assuming effective verification, enhance our security.

Answer: The inherent risks to U.S. security associated with the TTBT's constraints have been judged, on balance, to be acceptable in light of other considerations, including the following:

-- If provisions for effective verfication are agreed to, they will lay the groundwork for mutual confidence in the agreed obligations, thereby enhancing stability.

-- These two treaties, which we have scrupulously observed for over a decade, prohibit larger-yield nuclear explosions, such as tests once carried out by the Soviets at levels 15 to 20 times greater that 150 kt.

-- Although we have been prevented from pursuing modern high-yield technologies in order to live within the constraints of the TTBT, we believe we can field and will be able to field the new high-yield weapons for which we currently have firm military requirements.

-- The TTBT contains a clause that protects our right to withdraw in the event of a threat to our supreme national interests.

-- If the U.S. achieves the necessary verification improvements to the TTBT and PNET which we are seeking -- including the right of each side to conduct accurate, direct, hydrodynamic yield measurements at the site of all nuclear detonations of the other side which otherwise might appear to have yields in excess of 150 kt -- and maintains the appropriate safeguards, we can assure that these treaties place equal testing constraints on the nuclear warhead development programs of the U.S. and the Soviet Union.

At the same time, we have noted that the U.S. decision in 1976 to respect the limits of the unratified TTBT has limited the flexibility of our nuclear testing program in ways that we otherwise could not have limited ourselves, given the continuing Soviet programs to harden ICBM silos and command posts and the massive buildup in Soviet offensive and defensive capabilities since the TTBT was signed in 1974. Our last high-yield test took place in 1976 before the 150-kt TTBT limit took effect. High-yield weapons deployed since then or expected to be deployed in coming years -- including those carried by the Peacekeeper, Trident, B-1, and small ICBM -- have been, or will be, certified without validation by a full-yield test.

Q. (Helms) Please evaluate how compliance with TTBT over the last twelve years has affected U.S. security. In particular, was any defense research and development which might have been warranted by the evolving Soviet threat ever foregone or curtailed because of TTBT?

Answer: Overall, if adhered to by both sides and accompanied by the appropriate safeguards, these treaties would be consistent with our national security interests. While it is difficult to make an overall evaluation of the effects on U.S. security of compliance with the TTBT, we almost surely have had to confront the evolving Soviet threat in ways which we would not have selected in the absence of any TTBT constraint on our nuclear weapons program. For example, we have depended on one nuclear test, conducted in 1973, as the basis for a substantial portion of our most modern strategic nuclear warheads, including those for the Peacekeeper and D-5 missiles. This same test likely will provide the basis for future high-yield systems such as the small ICBM. It is probable that more efficient, effective, economical, and even safer designs would have been developed for these systems in the absence of TTBT constraints. It is reasonable to assume that we would have conducted a more recent full-yield confidence test to assure ourselves that changes we have introduced to the design of the tested precursor since 1973 have not significantly altered its performance. Under the TTBT constraints, we have had to rely on calculations and partial-yield tests to obtain such assurance.

At the same time, one of our major concerns is that Soviet designers may not have been as constrained by the TTBT as our designers have been. Any such asymmetry would become increasingly important over time, since we likely would continue to rely on tests that took place prior to the entry into force of the TTBT constraints as a basis for our warheads, whereas the Soviets might exploit our verification uncertainties to maintain high confidence in their existing high-yield designs and to better maintain and even improve the high-yield expertise of their nuclear weapon design and production establishment. This is an important reason for the President's decision to request the Senate's advice and consent to TTBT/PNET ratification subject to the condition as stated in the President's message to the Senate of January 13, 1987.

Q. (Helms) The President's reports to Congress have said that "Soviet nuclear testing activities for a number of tests constitute a likely violation" of TTBT, and that "these Soviet actions continued despite US requests for corrective measures." In this regard, please respond to the following:

A. Has the U.S. continued to raise these issues? If yes, in what forum?

Answer: The United States raises instances of Soviet violations of arms control agreements at every appropriate opportunity. Our concerns about violations of the 150 kt limit of TTBT have been raised in demarches to the Soviet government, as well as in bilateral meetings. To date, the Soviet responses have not been satisfactory.

B. Will the U.S. continue to raise these issues as it seeks to negotiate the additional verification provisions for TTBT?

Answer: The U.S. will continue to raise our concerns over likely violations of the TTBT that have taken place in the past, as well as any that might occur in the future.

C. Will resolution of the ambiguities which have led to the conclusion that the Soviets have likely violated TTBT be necessary before ratification of TTBT?

Answer: No, such ambiguities clearly demonstrate the need for effective verification measures to correct the verification inadequacies of the TTBT and the PNET, but resolution of ambiguities in the nature of past Soviet testing practices is not a prerequisite for ratification of the treaties, subject to the condition contained in the President's letter to the Senate of January 13, 1987. If, as we hope, the Soviets agree to necessary verification improvements to the TTBT/PNET as stated by the President, we are confident that ambiguities about Soviet test practices will be significantly reduced. Over time, the improved verification measures which we hope to negotiate may also cast light on the past ambiguities.

Q. (Helms) In his October 10, 1986 letter to Chairmen Goldwater and Aspin, the President said that after TTBT ratification he would propose talks on a "step-by-step parallel program -- in association with a program to reduce and ultimately eliminate all nuclear weapons -- of limiting and ultimately ending all nuclear testing." Understanding that there is not yet a position on what a first step might be, in theory, please explain how such a program would work. In particular, please address the following questions:

A. What might be the elements of a first step in such a process?

B. Would we first seek further limits on permitted yield, a yearly quota on the number of tests, or some other restrictions?

C. Is it possible now to predict what our defense needs will be in a world in which there are still nuclear weapons? For example, if President Kennedy or President Ford had agreed to say, a 50 kiloton limit, or a yearly quota on the numbers of tests, would we now be better or worse off?

D. What weapons would have to be eliminated to justify a further limit on testing? Would an entire class of weapons have to be eliminated, or could a further restriction be based on a percentage reduction of a weapon class, warheads, throwweight, etc.?

E. U.S. nuclear weapons requirements are driven not only by Soviet nuclear weapons, but also by other military improvements made by the Soviets such as their air defense and hardening. Would further limits on nuclear testing based on elimination of some nuclear weapons not also have to be based on elimination of certain non-nuclear assets or programs?

Answer: With respect to the U.S. step-by-step approach on nuclear testing, the President has made clear that the necessary first step in the process is to achieve effective verification of the TTBT and PNET. Once our verification concerns have been satisfied and the treaties have been ratified, our negotiators on nuclear testing can begin to address issues relevant to further steps. These further steps, of course, must be considered in the context of any specific steps taken to reduce and ultimately eliminate nuclear weapons negotiated in the Nuclear and Space Arms Talks.

Our testing requirements are not related directly to the size of the stockpile. Therefore, reductions in Soviet and American nuclear weapons will not lead to proportional reductions in testing. Even with negotiated arms reductions, nuclear testing will still be required to ensure the safety, reliability, effectiveness, and survivability of the remaining weapons -- in short, the credibility of our deterrent -- for as long as the U.S. and our allies must rely on nulcear weapons to deter Soviet aggression.

There may be some relationship, however, between the number of different nuclear weapon types in our stockpile and the number of tests required. For example, if an arms reduction agreement resulted in the elimination of an entire weapon type from the inventory, the requirement for reliability testing associated with that type would be reduced.

In the course of future negotiations on nuclear testing, it would be our task to identify those additional and effectively verifiable limitations on nuclear testing, if any, that are consistent with our need to maintain a credible nuclear deterrent as we achieve progress in a parallel program to reduce and ultimately eliminate all nuclear weapons. The ending of nuclear testing, in parallel with the elimination of nuclear weapons, is the ultimate step, not the first step, in negotiations on nuclear testing.

With regard to predicting future defense requirements, we obviously must respond to changes in the Soviet threat with necessary force modernization programs -- including our nuclear forces, examples of which are cited in the previous answer -- to maintain a credible deterrent. We cannot predict all future requirements, however, since the closed nature of Soviet society makes it very difficult -- in some cases, impossible -- to gather the information necessary to make a reasonable judgment on Soviet intentions or capabilities. Experience has shown that the Soviets can surprise us. Indeed, one of the key purposes for our nuclear testing program is to ensure that we keep abreast of Soviet nuclear-weapon developments and avoid any technological surprises -- for example, in the area of nuclear-driven X-ray lasers -- that might alter the strategic balance.

It is difficult to speculate on the consequences of actions that, in fact, were neven taken by past Presidents. As the President and other Administration officials have pointed out, nuclear testing has been and remains indispensable to ensure the safety, reliability, effectiveness, and survivability of our nuclear weapons. For example, testing allowed us to correct defects that were suddenly discovered in the Polaris submarine-launched ballistic missile; until corrected, these defects could have rendered the vast majority of our sea-based deterrent completely inoperable. In short, in the absence of a flexible nuclear testing program, which is conducted in compliance with our international agreements, the credibility and safety of the U.S. deterrent would not be as high as it is today, and the chances of Soviet aggression -- nuclear as well as non-nuclear -- against vital Western interests would accordingly be higher.

With regard to the final part of your question, it is true that our requirement for nuclear testing resonds to Soviet non-nuclear as well as nuclear developments. For example, Soviet programs in the area of strategic defense -- including anti-aircraft defenses and hardening of key military, leadership, and economic assets -- have obliged us to introduce modernized systems to maintain deterrence. This is one reason why even with negotiated nuclear arms reductions, nuclear testing will continue to be required as long as we must rely on nuclear weapons to deter aggression. In the course of future negotiations on nuclear testing, we would need to identify those additional and effectively verifiable limitations on nuclear testing that are consistent with our need to maintain a credible nuclear deterrent as we achieve progress in a parallel program to reduce and ultimately eliminate all nuclear weapons.

Responses of H. Allen Holmes to Questions Asked by Senator Sarbanes

Q. (Sarbanes) This reservation is unlike any reservation I have ever seen. Is there a comparable instance of such a reservation?

A. The condition specified by the President establishes a linkage between the TTBT and PNET and agreements for effective verification of those treaties. It is not unusual for linkages to be established between treaties to which the Senate gives its advice and consent and other international agreements. For example, the Panama Canal Treaty envisioned agreements in implementation of Articles III, IV and IX. The agreements in implementation of Articles III and IV were concluded on the same day as the Panama Canal Treaty but were not submitted to the Senate for advice and consent.

Article IX, paragraph 11, obligated the parties to conclude an agreement whereby nationals of either State convicted of offenses by the courts of the other State might elect to serve their sentences in their state of nationality. In its resolution of advice and consent to the Panama Canal Treaty the Senate adopted an understanding to the effect that the agreement called for by Article IX, paragraph 11, should "be concluded in accordance with the constitutional processes of both parties." The President concluded that agreement as a treaty; the Senate gave advice and consent on November 30, 1979.

On August 9, 1984 the Senate gave advice and consent to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region. Linkage between the Convention and related protocols was established by Article 24, which stated that no State could become a contracting party to the Convention unless it became at the same time a contracting party to at least one protocol to the Convention. Since the President decided that the first protocol to which the United States would become a party should be concluded as an executive agreement, it was not necessary to obtain advice and consent of the Senate to the protocol. Had the President decided to conclude the protocol as a treaty, a resolution of advice and consent to the protocol would have been required before the United States could have become a party to the convention.

Q. (Sarbanes) Would not [the approach advocated by the President]in effect preclude subsequently the possibility of ratifying the treaties as submitted...? [W]hat you have done here is that you have precluded that possibility, have you not?

A. While the treaties would no longer be before the Senate if the Senate adopted a resolution of advice and consent to ratification that included the condition recommended by the President, that would not preclude resubmission of the treaties in their original form to the Senate if the condition were not met. The Administration believes, however, that resubmission of the treaties, without the necessary improvements providing for effective verification, would be contrary to U.S. national security.

Q. (Sarbanes) Would adoption of a reservation that [the Administration has] submitted, conditioning acceptance of the treaty, to the subsequent agreements that must be submitted, lift that obligation under international law?

A. This issue was dealt with in the answer to 1(b),(c) and (d) submitted by Senator Kerry. The obligations on the parties under international law would not be affected by adoption of the condition posed by the Administration.

Additional Responses of H. Allen Holmes to Questions Asked by Senator Pressler

Q. (Pressler) Isn't it true that if the Soviets declared a test to be "peaceful" under PNE, then on-site inspection would not apply--even if we had excellent reason to believe that that test was really a military one?

A. No. We would seek the right to CORRTEX a certain number higher yield PNE's which might approach the 150 kt limit.

Q. (Pressler) I assume that under your current plans we would still exchange the physical data called for in the treaties. To enhance our ability, even using CORRTEX, isn't it necessary for us to confirm that the geophysical data we have been given by an initital on-site inspection? Otherwise, how would you use the data which you yourselves said would be unverifiable? If at some later point we wanted not to attend every test with CORRTEX, would we not need confirmed geophysical data to calibrate our teleseismic instruments?

A. Geophysical data may be important for the CORRTEX measurement in case unusual conditions are encountered. Validated geophysical data would also be helpful for improving the measurement accuracy for those tests for which our only measurements would be teleseismic. The most effective calibration of our teleseismic systems would be accomplished through the measurement of an appropriate number of Soviet tests of validated yield.

Q. (Pressler) Certain classified memoranda written by the U.S. intelligence community have recently been leaked, in part, to the press. I cannot raise these issues in an open session, but it is certainly clear that the subject of these memos is an issue of long-term concern: verification.

President Reagan has proposed a reservation to the treaty ratification that would acquire an additional agreement. My question is a simple one: How rigorous must these measures be?

a. initial inspection of Soviet testing sites to confirm Soviet information on the geophysical characteristics of the sites?

b. must we detonate American chemical devices at Soviet testing sites to check the accuracy of seismic detection systems.?

c. and do we need to establish monitoring stations on Soviet territory?

A. a. The President's reservation would require the negotiation of protocols to the treaties which provided for using on-site CORRTEX measurements as an effective technique to verify the nuclear test yield limit (150 kt) of the TTBT. For CORRTEX we are not as concerned about geophysical characteristics of the test site as would be the case for teleseismic measurements, but we must protect ourselves by collecting geophysical information in case unforseen conditions were to be encountered.

b. Because of the yield limitations inherent in chemical explosions and other factors, such explosions would be of marginal use in calibrating teleseismic yield estimation systems. Detection (i.e., whether or not a nuclear explosion has taken place) is not an issue when considering 150 kt yield limits.

c. Seismic monitoring stations on Soviet territory would not help or improve the CORRTEX method, but this capability would provide information of potential utility for future monitoring tasks. CORRTEX would remain however, our basic approach toward effective verification of the TTBT.

Responses of H. Allen Holmes to Questions Asked by Senator Lugar

Q. (Lugar) Since last summer three meeting of "experts" have taken place to discuss TTBT verification. Does the Administration plan to raise these to the political level in order to negotiate an agreement for effective verification?

Answer: Yes, we have proposed to begin negotiations on nuclear testing limitations, but the Soviets have so far failed to agree to our proposed essential agenda. At the third session of the Nuclear Testing Experts Meetings (NTEM) held November 13-25 in Geneva, the United States proposed that the meetings resume in January following a recess to allow further study of the issues. The objective of the talks is to seek agreement to the opening of negotiations on the first priority step in nuclear testing arms control -- the needed verification improvements to the TTBT and PNET. Once our TTBT and PNET verification concerns have been satisfied and the treaties have been ratified, we would immediately propose negotiations on ways to implement a step-by-step parallel program -- in association with a program to reduce and ultimately eliminate all nuclear weapons -- of limiting and ultimately ending nculear testing. The Soviets accepted our proposal to meet in Geneva on January 22, and we are hopeful that they will accept our proposal to begin negotiations soon on nuclear testing limitations in accordance with the priorities outlined above.

Q. (Lugar) In general terms, the Administration has said that effective verification would require direct, accurate yield measurement at the site of the nuclear detonations. Please explain the terms "direct yield measurement," "accurate," and "at the site."

Answer: By "direct measurement" we mean determination of some property of a system by looking at something we can measure which is simply and directly related to the property we are interested in. If we wanted to find the speed of a locomotive, we could make a "direct measurement" by using a stopwatch and looking at how long the locomotive took to cover a known distance on the track. If we were not allowed to see the locomotive, we might to try to infer its speed by looking at how much the rails vibrated when the locomotive was two or three miles down the track. We could estimate the speed this way, but it would require us to know mechanical properties of the tracks, the weight of the locomotive (as well as other things) with a mathematical way to relate all those things to speed. That is an example of an indirect measurement.

The CORRTEX technique measures the speed with which the high pressure shock wave from an explosion moves through the ground; that speed is simply related to the energy produced by the device, and, so provides a direct measurement of the yield. Seismic estimates of Soviet yields depend on knowing details of the geophysical properties of the test site to great depths and therefore are not considered direct yield measurements since such properties have to be inferred from assumptions and indirect evidence.

"Accurate" refers to the degree to which we can believe that the measurement allows us to truly determine what the actual yield was. An accurate measurement of the yield would allow us to have confidence that we knew the actual energy released by the nuclear device. The CORRTEX technique measures yields of interest in verifying the 150 kiloton limit to accuracies of 30% or better. We know of no other method which measures yields greater than 50 kilotons more accurately than CORRTEX without compromising sensitive information or adding unacceptable constraints.

"At the site" means that measurements are taken at the location of the test, that is a few meters away from the nuclear device and not miles or thousands of miles away. In the case of CORRTEX, measurements must be taken at the site of the explosion because the coaxial cable on which CORRTEX depends must be emplaced in the strong shock region in close proximity to the explosion. We also believe that allowing the presence of experienced monitoring personnel "at the site" would discourage attempts to cheat and would greatly increase mutual confidence in compliance with the treaties.

Q. (Lugar) If, after ratification, Soviet violations were detected, what measure would the Administration recommend to safeguard U.S. security?

Answer: Soviet violations of the TTBT/PNET would be a serious matter for U.S. national security interests. Such violations could raise the inherent risks of continued U.S. compliance with TTBT constraints. That said, Article V of the PNET creates a Joint Consultation Committee (JCC) which, *inter alia*, will consider questions concerning compliance with PNET obligations. Administration action to safeguard U.S. security in the event of a Soviet violation of the TTBT and PNET would depend on the nature of the violation. Depending on the circumstances, the Administration would pursue whatever means appropriate to address Soviet violations. The United States would exercise its rights under the treaties for consultation, amendment, or withdrawal if circumstances indicated a need to do so.

Additional Responses of H. Allen Holmes to Questions Asked by Senator Lugar

Q. (Lugar) TTBT was signed by President Nixon, and PNET by President Ford who also submitted them both to the Senate for advice and consent. When President Reagan came to office he decided that additional measures had to be negotiated to achieve effective verification. Is this policy based on circumstances which have changed in the dozen years since President Nixon signed the TTBT? If yes, please explain.

A. There have been changes in circumstances since the negotiation of the TTBT and the PNET which impact the requirements for treaty verification. This administration, at the outset, adopted a realistic policy of effective verification. Because of the record of Soviet testing and the findings of likely violations of the 150 kt limit, it is our judgment that our present yield measurement uncertainty is no longer acceptable to ensure effective verification of these treaties. We have found as well that during this period a direct, on-site procedure (CORRTEX), more accurate than teleseismic measurement, had been developed at the national laboratories.

Q. (Lugar) If TTBT were made effectively verifiable, what benefit to US national security and stable deterrence would be derived from the 150 kiloton limit?

A. Effective verification - and enforcement - of the TTBT 150 kt limit would significantly inhibit the Soviet intent to develop higher yield nuclear weapons or test the performance of higher yield systems in their stockpile and would contribute heavily to strategic stability. Moreover, there are other important benefits. Formal agreement to this limitation on nuclear testing, by ourselves and our principal adversary, would be seen by other parties as a positive and stabilizing step contributing to improved mutual confidence. Verifiable agreements if complied with, could open the path to more stable and predictable relations, including other arms control areas, with the Soviets.

Q. (Lugar) There has been coniderable controversy over the so-called bias used in calculating the yield of Soviet nuclear tests. What is the source of this controversy, and how can it be settled?

A. Without actual knowledge of the Soviet nuclear test yields, we cannot be certain of the relationship between the yields and the seismic signals received at our teleseismic monitoring stations. This is due to the fact that seismic signals originating in different parts of the earth undergo differing amounts of absorption as they pass through the earth on their way to the teleseismic monitoring station. The term "bias" refers specifically to the differences in signals received at one of our teleseismic monitoring stations from a U.S. Nevada test compared to the same yield test conducted at the Soviet site. Thus, it is not feasible to utilize our own nuclear tests in Nevada to achieve a direct calibration for the Soviet test sites. Our direct hydrodynamic yield measurements at Soviet test sites would go a long way toward remedying this situation.

Q. (Lugar) Some have argued that if we were to ratify TTBT and PNET we would benefit from the information exchanges and on site inspections these agreements already provide for. Please evaluate what these measures would or would not achieve for verification of the agreements.

A. The TTBT provides for exchange of test site geological data while the PNET also provides for a limited number of on-site direct yield measurements. The provisions for geological samples are of very limited value since we cannot be certain of their credibility. The data exchange of some Soviet yields, as provided in the treaty protocols, would also be of little assistance because of the same problem. Furthermore, at the time of signing the TTBT, we were concerned about the extent of geological variations across the test sites. Such variability could cause differences in coupling of the explosive energy to the earth and, thus, variability in the strength of the seismic waves detected. We do not now view this problem with as much concern as we did in 1974 because subsequent research has shown the Soviet test sites to be much more uniform in their geology.

Q. (Lugar) If the United States and the Soviet Union were to agree to use the CORRTEX system to verify the TTBT, would it be necessary to use it for all nuclear tests? If not, what kind of information would we need to determine how many and which tests need to be monitored with CORRTEX?

A. The CORRTEX system is presently the best approach for reducing uncertainties associated with verification of compliance with the 150 kt threshold. Moreover, we should consider this technique to be a part of a comprehensive monitoring regime, relying on a number of different data sources which would provide higher confidence than any single system, no matter how capable. It is not however our intention to measure all Soviet tests, and thus small explosions, say 10 or 20 kilotons yield, would not be measured. We would, therefore, wish to guarantee our right to CORRTEX measurement of any explosion which in the absence of such measurements might appear by teleseismic means, to exceed the 150 kt limit. In order to ensure this provision we require the right to measure all tests down to substantially lower levels than the limit.

Responses of H. Allen Holmes to Questions Asked by Senators Lugar/Helms

Q. (Lugar/Helms) If effective verification is agreed upon, and we proceed with TTBT and PNET ratification, are there steps permitted under the treaties which we should take in order to minimize the impact of Soviet violations, should they occur?

Answer: Article V, Paragraph 1 of the TTBT provides that the Parties may, as necessary, hold consultations to consider the situation relevant to the substance of the Treaty and to introduce possible amendments to the Treaty text. The PNET includes a similar provision at Article VIII, Paragraph 1. In addition, both treaties include provisions for withdrawal. The United States would exercise its rights under the treaties for consultation, amendment, or withdrawal if circumstances, including Soviet violations, indicated a need to do so. In addition, there are a number of diplomatic, military, and other actions which are available to us in the event the question of compliance arises.

Responses of H. Allen Holmes to Questions Asked by Chairman Pell

Q. (Pell) The Administration has said that the present range of uncertainty with regard to Soviet tests means that a 150 kt explosion could register as ranging from about 75 kt to about 300 kt. A more intrusive system, such as CORRTEX, would reduce the range of uncertainty, but not make it zero. How much uncertainty can the Administration live with and still consider it "effective verification?"

Answer: The Administration is committed to the principle that all U.S. arms control agreements must be effectively verifiable. The President in March 1986 formally communicated to General Secretary Gorbachev that if the Soviet Union accepted CORRTEX as the basis for effective verification of the Threshold Test Ban Treaty, he would move forward on ratification. The President also stated that the U.S. Government associates an accuracy of 30 percent, with 95 percent confidence, in CORRTEX yield estimation. CORRTEX is the most accurate yield-estimation technique known to us except for radiochemistry. Thus, it is clear that for the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty the Administration has identified a CORRTEX-derived yield estimation accuracy of 30 percent with effective verification.

Q.(Pell) Has the testing of CORRTEX been adequate for you to be certain that it can live up to its purported promise of yielding "effective verification?"

Answer: I believe the U.S. experience with CORRTEX has been such that it will provide effective verification of the TTBT and PNET when properly employed. The 30 percent accuracy for CORRTEX when used for verification is a conservative value. When the U.S. uses CORRTEX to estimate the yield of U.S. devices, our complete knowledge of the nature of the explosive and nature of the diagnostics has enabled us to achieve a 15 percent accuracy to those measurements.

Q. (Pell) How many times has CORRTEX been tested in the manner being proposed to the Soviets in which adjacent holes are used, rather than the main hole containing the nuclear device? With what result?

Answer: The Department of Energy has used CORRTEX to measure the yield of over 100 U.S. nuclear explosions. The DOE has used CORRTEX on five occasions in a satellite hole adjacent to the emplacement hole rather than in the emplacement hole containing a nuclear device. On one of those occasions, we investigated possible spoofing techniques which others might employ to interfere with CORRTEX measurements. It should be noted that the spoof would have been readily detected under the conditions that we intend to propose as part of any Threshold Test Ban Treaty/ Peaceful Nuclear Explosions Treaty verification package. In any case, the results of CORRTEX measurements in satellite holes are totally consistent with all other CORRTEX measurements, and even in the spoofing the results were well within the 30 percent accuracy which we attribute to CORRTEX when used as a verification tool.

Q. (Pell) How effective is CORRTEX at verifying yields at lower levels such as 75 kt, 10 kt, and 1 kt?

Answer: The President has informed the Soviet Union that we associate an accuracy of 30 percent with CORRTEX, when used as a verification tool, for yields above 50 kt. Under the conditions appropriate for verification, our experience for measurements of tests significantly below 50 kt is limited. There are no presently identified scientific reasons that the accuracies obtainable below 50 kt should degrade significantly; however, there are operational and engineering procedures that would have to be addressed.

Q. (Pell) In 1974, seismic verification was considered adequate, and it was known what the uncertainties were. Now, in 1987, one would expect seismic verification to be much better. What has happened to make the Administration believe that seismic verification is not enough?

Answer: We have had to alter our calculational methods drastically since 1974, demonstrating that we did not know what uncertainties existed in the teleseismic methods when the TTBT was signed. If anything, our research since 1974 has, in general, only made us more aware of the limitations inherent in seismic monitoring techniques.

Among verification objectives, two key ones are: (1) to insure that militarily-significant violations can be identified in a timely manner; and (2) to avoid uncertain or inaccurate charges of violation.

During the almost 13 years since the Threshold Test Ban Treaty was signed, seismic data has resulted in yield estimates which are consistent with a number of Soviet tests in excess of 150 kt. Certainly, if in fact the Soviets have conducted tests above 150 kt, they clearly have done so for reasons which they think are militarily significant. On the other hand, if the Soviets have not tested above 150 kt, then the seismic monitoring techniques have resulted in many knowledgeable people unfairly believing that the Soviets have cheated. At the same time, even though we have scrupulously complied with the terms of the TTBT, the Soviets have questioned U.S. compliance with the 150-kt threshold. Thus, the current uncertainty and debate about likely Soviet violations of the TTBT clearly constitute a source of friction and controversy inconsistent with the objectives of verification and of the treaties. For these reasons, the Administration believes that seismic monitoring techniques are clearly not enough to provide effective verification of the Threshold Test Ban and Peaceful Nuclear Explosions Treaty.

Q. (Pell) If the Soviets simply do not agree to use hydrodynamic means, such as CORRTEX, will you be able to reach agreement?

Answer: The U.S. Government requires the adoption of a verification mechanism which will achieve a yield-estimation accuracy of at least 30 percent, with 95 percent confidence, in order to find that the Threshold Test Ban Treaty is effectively verifiable. If another means for direct yield measurement can be identified and demonstrated which is capable of an accuracy of at least 30 percent, and which, like CORRTEX, can provide accurate yield estimates without danger of compromising sensitive information or adding unacceptable constraints, it could be the basis for reaching an agreement.

Responses of H. Allen Holmes to Questions Asked by Senator Kerry

Q. (Kerry) What are the legal consequences, under both international law and under domestic law, of the Senate approving the TTBT and the PNET with the condition to the TTBT and PNET specified by the President in his Message to the Senate January 13, 1987?

(a) Does such an approval, with the condition specified, constitute approval of the Treaties by the Senate under U.S. law?

A. Under U.S. law adoption by the Senate of a resolution of advice and consent to ratification to TTBT and the PNET with the condition specified by the President in his January 13, 1987 Message to the Senate would constitute advice and consent to ratification of those treaties on the terms specified.

The Senate has adopted a number of resolutions of advice and consent containing conditions that must be satisfied prior to exchange or deposit of instruments of ratification. Among the most recent is that for the Genocide Convention, which provides that the U.S. instrument of ratification is not to be deposited until the Congress has enacted the necessary implementing legislation.

An example of a resolution of advice and consent to an arms control agreement containing a condition is that adopted by the Senate in 1934 in respect of the Convention for the Supervision of International Trade in Arms and Ammunition signed at Geneva on June 17, 1925. The resolution contained a provision denominated a reservation to the effect that the Convention should not come into force so far as the United States was concerned "until it shall come into force in respect of nine named countries. Several of the countries named had also specified that this Convention would not come into force for them until it had come into force for certain other countries, including the United States. While the Senate gave its advice and consent to ratification many years ago, the treaty has never entered into force for the United States since the terms of the resolution have never been met.

> (b) Does such an approval, with the condition specified, permit the U.S. or Soviet Union, at their discretion, to conduct tests prohibited by the Treaties pending the negotiation of revised verification provisions?

A. It does not affect the existing obligations of the United States or the Soviet Union under international law not to defeat the object and purposes of the two treaties pending ratification.

> (c) Does such an approval, with the condition specified, constitute a legal justification under international law, or applicable U.S. or Soviet law, for either party to conduct tests prohibited by the treaties pending the negotiation of revised verification provisions?

A. Approval by the Senate of the treaties with the conditions specified by the President would not constitute a legal justification under international law or under U.S. law to conduct tests over the treaty thresholds pending the negotiation of revised verification provisions. To the best of the Department's knowledge, it would not constitute a legal justification for such testing under Soviet law.

> (d) What is the legal effect, if any, of such an approval, with the condition specified, in terms of the obligations created or lifted on either party to the Treaties?

A. None.

Q. (Kerry) What are the legal benefits to the U.S. of approving the Treaties with the condition? Please compare any such benefits with the legal consequences of the Senate taking no action on these Treaties at this time.

A. This proposal would strengthen the ability of the Executive Branch to negotiate appropriate verification agreements which are the necessary prerequisite for ratification by the United States. If the treaties were to be ratified, they would have full legal force and effect for the United States and the Soviet Union; without such ratification, their legal effect will be limited to the obligations flowing from customary international law not to defeat the object and purpose of a treaty pending ratification.

Q. (Kerry) Does attaching the condition to the Treaties create a precedent for the Soviet Union or any other nation to attach conditions to these or other Treaties to which the U.S. is a party? Are there any adverse or negative consequences to U.S. interests of such a precedent?

A. As illustrated by the Senate's resolution of advice and consent to the Supplementary Extradition Treaty with the United Kingdom last session, precedents already exist for attaching conditions to resolutions of advice and consent. The disadvantage most often attributed to such a practice, which could be relied on by other States in other contexts, is that conditions that purport to exclude or modify the legal effect of certain provisions of a bilateral treaty can reopen the negotiation or require the other party to accept a condition to which it was unwilling to agree during the negotiations. On the other hand, there are cases where the treaty will never enter into force unless changes are made. The Administration believes that a resolution of advice and consent to the Treaties subject to the condition specified in the President's Message would enhance the prospects for successful negotiation of effective verification agreements, in the absence of which the President would not proceed with ratification.

Responses of H. Allen Holmes to Questions Asked by Senator Pressler

Q. (Pressler) How detailed would our agreement have to be on the rights of the personnel checking tests with CORRTEX, and on the obligations of the host state?

A. The question of the appropriate level of detail is, of course, a matter that would need to be addressed in the negotiations with the Soviets. However, the Peaceful Nuclear Explosions Treaty (PNET), which provides for on-site verification in certain limited circumstances, illustrates the broad range of issues that arise in connection with new verification agreements incorporating CORRTEX.

The details of the verification regime for the PNET are contained in the Protocol to that treaty, consisting of ten articles. Among other things, the Protocol provides for information regarding planned explosions to be furnished at specified times and in specified degrees of detail (Article II); it sets forth the rights of inspection personnel to confirm data, to observe explosions, to make yield measurements with electrical equipment, to establish a local seismic network, and to obtain photographs (Article III); it describes the equipment that may be used by inspection personnel and the precise manner in which such equipment shall be brought to the site, installed and operated (Articles IV and VI); it specifies the locations at which, and the times during which, the inspection personnel may perform their functions (Article V); and it clarifies the rights and obligations of the parties with respect to payment of inspection-related expenses, responsibility for the conduct of the explosion, and the handling of proprietary information (Articles V, VIII and IX). In addition, since verification would involve the presence of U.S. inspection personnel in the Soviet Union and vice versa, the PNET Protocol provides that such personnel, and their property and temporary quarters, shall be accorded the same privileges and immunities as provided in specified articles of the Vienna Convention on Diplomatic Relations of 1961 (Article VII).

It may be possible to incorporate some portions of this regime by reference in the provisions on CORRTEX, but this would have to be determined in the process of negotiation.

Additional Responses of H. Allen Holmes to Questions Asked by Senator Helms

Q. (Helms) If the treaties are indeed in our interest, then it is necessary to establish that effective verification is, at least in theory, possible. The U.S. has suggested use of the CORRTEX hydrodynamic system to measure the yields of tests. This would reduce our margin of uncertainty from the current 100% to 30%. Using currently available monitoring techniques, the Soviets could test up to 300 kilotons before we would be certain that a violation had taken place. Please explain why this is judged as effective verification. In particular, please answer the following questions.

a. What benefit can they now derive from testing up to 300 kilotons which would be denied them if they were limited to 195 kilotons?

b. Could they accrue any significant advantage by testing up to 195 kilotons while the United States observed the limit of 150 kilotons?

A. a. The President has determined that seismic techniques do not provide for effective verification and has proposed the use of on-site direct yield measurements (CORRTEX) which can provide, for Soviet test yields, an overall accuracy of a factor of 30 percent. This means that a Soviet test for which we estimate a "central yield" value of 150 kt may -- with a 95 percent probability -have indeed been a yield as high as 195 or as low as 105 kt. If the Soviets were to think that they could actually test at 300 kt, the data from such a test would be indicative of a treaty violation. The benefits derived from testing up to 300 kt, rather than 195 kt, include full yield tests of of warheads up to 300 kt thus providing higher confidence in the performance of such warheads. In addition, partial yield testing at 300 kt rather than 195 kt would enable the Soviets to have greater confidence in a higher yield warhead.

b. Similar comments would generally apply to partial yield testing at 195 kt versus 150 kt, but at this difference in yield, the military benefit would be smaller. Actually, the the vast majority of the Soviet strategic stockpile would have been recertified by partial yield testing on the order of 250 - 300 kt.

Q. (Helms) The United States and the Soviet Union agreed to an understanding which would allow "one or two slight unintended breaches per year" of the 150 kiloton limit. What advantages could the Soviets accrue by testing regularly up to 195 kilotons and testing once or twice per year at higher yields.

A. Testing by the Soviets above the 150 kt level would provide some increased confidence in their large-yield warheads. It should be noted that regular testing at 195 kt would produce teleseismic data indicating a very high probability of 150 kt threshold violation and, therefore, would trigger a strong US response. Little military advantage would be gained from such a procedure.

Q. (Helms) The President's report has also indicated that the Soviets have violated the Limited Test Ban Treaty of 1963 with nuclear testing practices which resulted in the "venting of radioactive matter on numerous occasions and caused radioactive matter to be present outside the Soviet Union's territorial limits." In testimony before this Committee last May, Assistant to the Secretary of Defense Barker indicated that this practice is now routine. Would the President ratify the TTBT before violations of another nuclear testing treaty, LTBT, are resolved?

A. Our present objective is to achieve effective verification for the TTBT and the PNET. We do not believe that LTBT problems should be linked with TTBT verification efforts. The venting violation of the LTBT, though serious, is an environmental problem, different from our concerns with verification of the TTBT. The achievement of improved TTBT verification capability would be a positive development because of its encouragement of a more straightforward and factual relationship with the Soviet Union. If we can, indeed, strengthen confidence in our dealings with the Soviet side, this might be helpful in the solution of the LTBT problem.

Q. (Helms) This Administration has clearly demonstrated that many arms control treaties to which the U.S. is party are severely lacking in verification. It has also shown that an even greater problem is enforcing compliance after detecting a violation. In this regard, please respond to the following:

a. What plans does the Administration have to minimize the impact of any Soviet violations, whether undetected, or undetected for a time and later discovered?

b. In what forum would the United States raise suspected violations of TTBT?

c. If violations are discovered, raised with the Soviets, but not resolved, what action should the U.S. take?

A. a. The best means of addressing the current ambiguities over Soviet violations is the negotiation of effective verification of the TTBT and PNET. In the attempt to assure that the US can take steps in a timely and effective manner to reduce the impact of Soviet violations, should they be detected, the JCS has called for the conduct of a governmental review at periodic intervals to determine if renewal of the Treaties is in the U.S. interest. Further, in his statement of January 13, 1987, Lieutenant General Vesser stated that "it is imperative that appropriate safeguards be adopted to reduce the military risks associated with these (the TTBT and PNET) Treaties." The safeguards proposed by the JCS include continued underground nuclear test programs consistent with Treaty limitations, maintenance of modern nuclear laboratory facilities, maintenance of basic capability to resume nuclear tests in prohibited environments and yield ranges, a vigorous verification program, and continued emphasis on intelligence capabilities.

b. Questions of compliance are currently transmitted via diplomatic channels on a case-by-case basis. Article II of the PNET, however, provides for the establishment of a Joint Consultative Commission (JCC)

c. If Soviet violations are discovered, raised with the Soviets, but not resolved, the US will have a range of possible responses under international law, including suspension of the operation of the agreement in whole or in part. Specific political, military or other responses would also be available to minimize the effect of soviet violations.

Responses of Lt. Gen. Dale A. Vesser to Questions Asked by Senator Kerry

Senator Kerry: In your testimony before the Senate Foreign Relations Committee, you refer to a revision of the Safeguards adopted in conjunction with the Limited Test Ban Treaty (LTBT), which you have forwarded to the Secretary of Defense for inclusion in the ratification process, and which have been provided to this committee.

This revision includes Safeguard "C", maintenance of the basic capability to resume nuclear tests in prohibited environments and yield ranges, should they be considered essential to our national security.

Have you undertaken any study of the costs of maintaining this capability? If so, what are the budgetary consequences of the adoption of this revision, if any, over the next 10 years?

LTG Vesser: Since the LTBT was ratified, the JCS have assessed almost annually the adequacy of support for the safeguards to the LTBT. Included in these assessments has been a review of funding, facilities and personnel involved in maintaining those assets which would support a resumption of atmospheric testing should such testing be determined essential to our national security. It is important to point out that many of these assets are currently being used on a non-interference basis by tenant organizations. Over the past 7 years DoD funding for facilities maintenance and support has averaged approximately $10.5 million (1980 dollars) per year and we do not foresee any near-term changes. The revision to Safeguard C to include maintenance of a basic capability to conduct testing promptly in prohibited yield ranges requires preserving the potential capabilities of our existing test sites. That is, no actions should be taken that would preclude testing above 150 kilotons. Currently there are no requirements which would add significantly to the cost of maintaining existing test facilities to support the revised Safeguard C. However, should there be a changing threat, it is possible that future requirements may involve increased capabilities and expense.

Senator Kerry: In your testimony, it was suggested that the basic capability to resume nuclear tests in prohibited environments and yield ranges was "essential to our national security" to respond to Soviet breakout of the treaties. Are there other circumstances which you believe would justify US testing in prohibited environments or yield ranges? If so, please specify under what conditions you believe such testing would be justified under the terms of the revision.

LTG Vesser: Our nuclear forces will deter the Soviets only to the extent that our forces can put at risk their high value targets. If the Soviets harden their high value targets beyond the threat of our current weapons (which they are attempting) we will need some new weapons and in some cases high yield weapons.

Also, the Soviets can negate the effectiveness of our deterrence through actions which are unconstrained by any treaty such as developing denser and more effective air defenses, employing new anti-submarine warfare techniques and/or adopting passive defensive measures.

If the Soviets took that grave step of breaking out of the LTBT and/or TTBT/PNET, they would surely have a strong motive -such as testing first-strike systems to destroy our retaliatory forces in place, testing defensive systems to render our deterrence ineffective or simply to unnerve the US leadership in a crisis.

Depending on the capabilities of the weapon laboratories to meet the requirements under the existing testing limitation, high-yield tests in prohibited environments may be the only alternative to meeting the threat. The revised Safeguard C proposed by JCS is a prudent hedge irrespective of any specific foreseeable testing needs. We simply are unable to predict what challenges the Soviets will present 10, 20 or 30 years hence, but we must not foreclose the options to meet all challenges.

Senator Kerry: It has been suggested that field testing of the x-ray laser and other directed energy weapons powered by nuclear explosives may someday be necessary if the United States is to proceed with the development and deployment of strategic defenses.

Under the terms of the revision, do you believe that such weapons could be tested in prohibited environments and yield ranges upon a finding by the President that such tests were "essential to our national security," despite the prohibition of the Treaty?

LTG Vesser: We do not anticipate any requirements to conduct nuclear tests beyond treaty limitations in support of strategic defense programs. The currently planned nuclear tests in support of strategic defense research, which are compliant with existing treaties, satisfy program requirements.

Senator Kerry: If so, do you believe that it would be sufficient for the President to certify that such tests were "essential to our national security," regardless of whether the Soviets had neutralized our deterrent, or would the President be required to make a finding that our deterrent was threatened, before making the certification that testing in the prohibited environments or yield ranges was essential to our national security.

See preceding answer.

Senator Kerry: In your testimony, you call for a periodic review of these treaties to determine if their renewal is in the US national interest. Do you believe that the President can authorize testing in the prohibited environments or yield ranges in the absence of such a review? If so, under what circumstances?

LTG Vesser: Safeguard F calls for the conduct of a periodic independent governmental review to determine if renewal of the treaties is in the US national interest. This review would provide advice to the President and I doubt that any President would authorize prohibited tests without considering the findings of that review.

Responses of Lt. Gen. Dale A. Vesser to Questions Asked by Senator Pressler

Senator Pressler: What exactly are the specific returns to the US in the military field of treaty ratification? Testimony this morning seems to support that the only militarily useful return would be more data. Yet, apparently, that data still cannot be verified effectively. Is this correct? Are there any additional military returns to the agreements as stated, with the reservation as stated?

LTG Vesser: We think what we are going to get out of it, with effective verification, is the confidence that the Soviets are equally and mutually restrained, as we have been, by observing the 150 kiloton test limit. Specifically, if they exceed that limit there is a possibility that they can move ahead in high yield weapons design, a matter clearly of some concern given their greater throw weight. So we see that such a treaty, with this kind of threshold and with adequate verification, will limit them and they will not get a military advantage.

The TTBT in its present form is simply not verifiable. As the TTBT now stands, tests yields are estimated by seismic means, which are assessed to have a factor of two uncertainty level. Also, the TTBT in its present form has no provisions for validation of the geophysical and calibration yield data which the Soviets would provide. Even if validated, the data would not be sufficient to reduce the uncertainty factor of two in our estimates of yields of Soviet nuclear weapons tests. The improved verification regime (subject of the reservation) has been sought by President Reagan and supported by the JCS since 1982. Under this regime, all Soviet weapons tests that might raise compliance questions would be measured directly by US personnel. The JCS judge that this direct yield measurement approach will provide effective verification because direct yield measurements will be subject to a much smaller uncertainty than seismic methods and the level of intrusiveness will be acceptable. Because of the many asymmetries that figure in the military balance, equal constraints on the yields of weapons do not necessarily imply equal military effects. For this reason, JCS support of ratification assumes the adoption of appropriate safeguards as well as the achievement of effective verification.

Responses of Lt. Gen. Dale A. Vesser to Questions Asked by Chairman Pell

Senator Pell: Should the Committee alter the language in Safeguard "C" so that everything after the word "ranges" is deleted and the following wording substituted: "...should the treaty be abrogated"? Would such a change be consistent with the intentions of the JCS?

Safeguard "C" as submitted by JCS:

The maintenance of the basic capability to resume essential nuclear test programs, in prohibited environments; and to conduct testing promptly in prohibited yield ranges, should such tests be deemed essential to our national security.

Safeguard "C" as altered by question above:

The maintenance of the basic capability to resume essential nuclear test programs, in prohibited environments; and to conduct testing promptly in prohibited yield ranges, should the treaty be abrogated.

LTG Vesser: No, Senator, it would not be consistent with the intentions of the JCS. Although Soviet abrogation of the LTBT and/or TTBT would almost certainly threaten US national security, I hope no one has the belief that possible Soviet abrogation of these treaties is the only reason we need to maintain a readiness to test in prohibited environments and/or ranges.

As I pointed out to Senator Kerry, the Soviets' program of hardening their high-value assets does not violate any treaty but it has the potential for neutralizing our ability to hold those targets at risk. To circumscribe Safeguard C as a hedge only against Soviet abrogation of the LTBT or TTBT would deny us what might prove to be a necessary option for dealing with an increasingly difficult hard-target problem. In 1963, during Senate consideration of LTBT, President Kennedy pledged a readiness-to-test safeguard, citing two independent grounds under which the safeguard would be invoked: first and foremost, national security, and second, Soviet abrogation of the treaty. Thus, an appropriate readiness-to-test safeguard is needed to respond to such a contingency.

Responses of Robert B. Barker to Questions Asked by Chairman Pell

AGREEMENT POSSIBILITY

QUESTION: If the Soviets simply do not agree to use hydrodynamic means, such as CORRTEX, will you be able to reach agreement?

ANSWER: The U.S. Government requires the adoption of a verification mechanism which will achieve a yield estimation accuracy of at least 30 percent, with 95 percent confidence, in order to find that the threshold test ban treaty is effectively verifiable. If a non-hydrodynamic means can be identified and demonstrated which is capable of an accuracy of at least 30 percent, it could be the basis for reaching an agreement.

RANGE OF UNCERTAINTY

QUESTION: The Administration has said that the present range of uncertainty with regard to Soviet tests means that a 150 kt explosion could register as ranging from about 75 kt to about 300 kt. A more intrusive system, such as CORRTEX, would reduce the range of uncertainty, but not make it zero. How much uncertainty can the Administration live with and still consider it "effective verification?"

ANSWER: The Administration is committed to the principle that all US arms control agreements must be effectively verified. The President in March 1986 formally communicated to General Secretary Gorbachev that should the Soviet Union accept CORRTEX as the basis for effective verification of the threshold test ban treaty that he would move forward on ratification. The President also stated that the US Government associates an accuracy of 30 percent, with 95 percent confidence, in CORRTEX yield estimation. Thus, it is clear that for the threshold test ban treaty the Administration has identified a yield estimation accuracy of 30 percent with effective verification.

CHANGE OVER YEARS

QUESTION: In 1974, seismic verification was considered adequate, and it was known what the uncertainties were. Now, in 1987, one would expect seismic verification to be much better. What has happened to make the Administration believe that seismic verification is not enough?

ANSWER: We have had to alter our calculational methods drastically since 1974, demonstrating that we did not know what uncertainties existed in the teleseismic methods when the TTBT was signed. If anything, our research since 1974 has in general only made us more aware of the limitations interest in seismic verification.

Verification should have two objectives: (1) To insure that militarily significant violations can be identified in a timely manner. (2) To avoid uncertain or inaccurate charges of violation.

With respect to the second objective, Ambassador Warnke, when testifying before the Senate Foreign Relations Committee on Thursday, July 28, 1977, said

> "It seems to us that verification is absolutely essential when you are dealing with nuclear explosives, test bans or limits, because otherwise you end up with a treaty which is a source of friction and controversy rather than one which is an improvement in bilateral relations and one which is genuinely effective."

[Editors Note.--The above quotation was also cited by Dr. Barker in testimony on January 13, 1987. In response to an inquiry requested by Senator Sarbanes, Ambassador Warnke provided the following comment:

"The TTB and PNE treaties were negotiated in 1974 and 1976, respectively, by Republican administrations. They were verifiable then, and given continuing advances in seismological technology, they are even more verifiable now.

The quotation taken from my 1977 testimony was testimony in support of the ratification of these two treaties without reservation. That was my position then, and it is my position today."]

During the almost 13 years since the threshold test ban treaty was signed, seismic data has resulted in yield estimates which are consistent with Soviet tests in excess of 150 kt. These estimates concern us since we know that modern warheads with yields over 150 kt can be tested--within the uncertainty--at full yield or at a significant fraction of the design yield. Certainly, if in fact the Soviets have conducted tests above 150 kt, they clearly have done so for reasons which they think are militarily significant. On the other hand, if the Soviets have not tested above 150 kt, then the seismic verification techniques have resulted in many knowledgeable people unfairly believing that the Soviets have cheated. Conversely, even though we have scrupulously complied with the terms of the TTBT, the Soviets have also questioned US adherence to the 150-kt threshold. Thus, the current uncertainty and debate about likely Soviet violations of the TTBT clearly constitute "a source of friction and controversy" which Ambassador Warnke correctly identified as inconsistent with the objective of verification. For these reasons, the Administration believes that seismic verification is clearly not enough for the Threshold Test Ban and Peaceful Nuclear Explosions Treaty.

CORRTEX TESTING

QUESTION: How many times has CORRTEX been tested in the manner being proposed to the Soviets in which adjacent holes are used, rather than the main hole containing the nuclear device? With what result?

ANSWER: The Department of Energy (DOE) has used CORRTEX to measure the yield of over 100 US nuclear explosions. The DOE has used CORRTEX on five occasions, in a satellite hole adjacent to the implacement hole rather than in the implacement hole containing a nuclear device. On one of those occasions, we investigated possible spoofing techniques which others might employ to interfere with CORRTEX measurements. It should be noted that the spoof would have been readily detected under the conditions we intend to propose as part of any Threshold Test Ban Treaty/Peaceful Nuclear Explosions Treaty verification package. In any case, the results of CORRTEX measurements in satellite holes are totally consistent with all other CORRTEX measurements and even in the spoofing were well within the 30 percent accuracy which we attribute to CORRTEX when used as a verification tool.

DIFFERENT SEISMIC METHODS

QUESTION: Is it not correct that, over the past 10 years, tremendous advances have been made in our understanding and abilities with various seismic methods? Has the intelligence community explored and used all available seismic methods in attempts to reduce uncertainties?

ANSWER: I believe that in the past 10 years advances have been made in our understanding of seismology, including its shortcomings when used as a yield estimation technique. Thus, in my opinion, seismology cannot be the basis for effective verification of the Threshold Test Ban Treaty and Peaceful Nuclear Explosions Treaty. The problem is that seismic methods are indirect yield estimation techniques. Even if calibrated, they will still have residual systematic errors or biases unknown to us, but possibly known to and exploitable by the Soviets. That is why the President chose CORRTEX for effective verification. Hydrodynamic methods--like CORRTEX-- are direct yield measurement techniques which do not have unknown bias factors associated with them.

I believe the Intelligence Community has vigorously pursued the application of all scientifically statistical seismic methods and nonseismic methods as well in attempts to reduce the uncertainties in our ability to estimate Soviet nuclear test yields. However, the verification uncertainities involved in seismic methods remain unacceptably high.

CORRTEX AT LOWER LEVELS

QUESTION: How effective is CORRTEX at verifying yields at lower levels such as 75 kt, 10 kt, and 1 kt?

ANSWER: The President has informed the Soviet Union that we associate an accuracy of 30 percent with CORRTEX, when used as a verification tool, for yields between 50 and 150 kt. Under the conditions appropriate for verification, the accuracy degrades rapidly below 50 kt, such that for 10 kt or 1 kt CORRTEX or, for that matter, any other known verification technique, is inappropriate for accurately estimating yield.

ADEQUATE BASIS

QUESTION: Has the testing of CORRTEX been adequate for you to be certain that it can live up to its purported promise of yielding "effective verification?"

ANSWER: I believe the US experience with CORRTEX has been such that it will provide effective verification of the TTBT and PNET when properly employed. The 30 percent accuracy for CORRTEX when used for verification is a conservative value. When the US uses CORRTEX to estimate the yield of US devices, our complete knowledge of the nature of the explosive and nature of the diagnostics has enabled us to achieve a 15 percent accuracy to those measurements.

Prepared Statement of Roger E. Batzel

1. Introduction

As long as our national security depends on the deterrence of war with nuclear forces, I believe that continued testing is necessary to maintain this deterrence capability and that restrictive nuclear test limitations are not in our national interest. Our deterrent depends on nuclear testing and the Soviets know this.

As the Director of a Laboratory largely devoted to nuclear weapons research, I have the responsibility to certify that the weapons that have been designed at my Laboratory will function when and if they are ever needed. I have the responsibility to spell out the technical consequences of nuclear test limitations on the viability of our nuclear deterrent and on my ability to perform the necessary certification. You have the difficult responsiblity of judging my arguments, weighing these technical risks against any real and political value of nuclear test limitations.

There is a widespread (though incorrect) perception that nuclear testing fuels the arms competition between the superpowers. Because of this perception, more restrictive test limitations have been proposed to allay the fears that people and nations have about the threat of nuclear war. Nuclear explosives, if used in war, could destroy civilization. But the tests which made this outcome possible have long since been done. Treating their successors as similar in purpose and impact leads to an unrealistic policy. I personally believe that the continuing appeal of a nuclear test ban stems from an erroneous concept of what nuclear tests are all about.

The current U.S. nuclear weapons program is already being conducted under a number of limitations. These include the Threshold Test Ban Treaty (TTBT), which limits underground explosions to 150 kt, and the Limited Test Ban Treaty (LTBT), which bans explosions in the atmosphere. In spite of these limitations, we have been successful in carrying out the major parts of our mission. Additional limitations will place our ability to perform that mission in jeopardy. My testimony will discuss the impact of test limitations and associated verification issues.

Modern nuclear weapons are complex technical devices which have been optimized and tightly integrated into an overall weapon system. Nuclear weapons operate at conditions which are virtually unique: the material speeds are millions of miles per hour, the temperatures and pressures are hotter than the center of the sun and the timescales are billionths of a second. We frequently cannot predict how a given nuclear weapon design will perform until it is tested. We cannot take all the information measured by non-nuclear means and make the extrapolations into the nuclear performance regime. We cannot always accurately assess the implications of aging which occurs in nuclear weapons, without nuclear tests.

There are four basic reasons why we have nuclear tests. First, we test to maintain the proper functioning of the stockpile of weapons we currently have. Second, we test to modernize the existing stockpile of weapons for enhanced safety, security or effectiveness or in response to the changing Soviet threat. Third, we test to measure the effects of nuclear weapons and ensure the survivability of our weapon systems and critical command, control, and communications which might be attacked by Soviet nuclear weapons. Finally, we test to avoid technological surprise by maintaining the scientific judgment necessary to understand the limits of nuclear weapon potential and by providing future options to the national decision makers. A fairly complete and unclassified summary of the role of nuclear testing is contained in Reference 1, which I would like to insert for the record.

2. Stockpile Confidence

Nuclear weapons are fabricated from chemically and radiologically active materials. Much as a piece of plastic that becomes brittle when left in the sunlight, nuclear weapons age and their characteristics change in subtle, often unpredictable ways. Testing is required to both find problems and to assess the adequacy of fixes which are implemented. Hard experience has shown that testing is essential. Approximately, one-third of all modern weapon designs placed in the U.S. stockpile have required and received postdeployment nuclear tests for resolution of problems. In three-fourths of these cases, the problems were discovered only because of the ongoing nuclear testing. Because of our inability to understand the effects of small changes on the nuclear performance, nuclear testing has been required to maintain the proper functioning of our nation's deterrent.

All nuclear tests contribute to the data base for assessment and understanding of stockpile problems. In this respect every test is related to stockpile confidence. In addition, we perform dedicated tests with the specific purpose of verifying stockpile units.

The importance of testing should not come as a surprise to anyone familiar with complex military hardware; the life history of any piece of military hardware is filled with continual testing followed by small changes to correct deficiencies. Many of you here on Capital Hill have advocated increased reliability testing of advanced conventional weapons. A nuclear weapon is usually tested fewer than 10 times during its 20 year lifetime. Yet its predictability is fundamental to deterrence and our survival.

While many problems occurred in earlier systems (Reference 2), there are a number of relatively recent problems (Reference 3) that have been identified and resolved only by nuclear testing. In one case, deterioration of a weapon component was observed during normal stockpile surveillance, and the weapon designers judged the problem to be serious enough to require a design modification. The component was redesigned and a nuclear proof test was required to certify that the new design would perform properly.

In another case, a test of a stockpiled weapon, tested under certain aging conditions to be expected in the stockpile, gave an unexpected reduction in yield. The weapons designers suspected that various engineering design features incorporated in the weapon after the physics-design nuclear tests were successfully completed may have had an adverse effect on the operation of the weapon. Design changes were made, and a second test was conducted to verify that the weapon would meet its military requirements.

In a third case, a final proof test at the weapon's specified low-temperature extreme was done just after deployment of the weapon had begun. The test results were a complete surprise. The device gave only a small fraction of its expected yield. The weapon had been tested extensively in nonnuclear hydrodynamic tests (including nonnuclear tests at low temperature) with no indication of trouble. Thus, on the basis of the nonnuclear testing and previous successful nuclear tests, the weapons designers had every reason to believe that the low-temperature proof test would produce the predicted yield. After extensive post-test analysis, the design was modified and another low-temperature nuclear test was performed. The test of the modified design was successful, and confidence was established that the warhead would operate properly over its entire temperature range. Thus, the appropriately modified design entered the stockpile. This experience also led us to reexamine other already stockpiled weapons and weapons under development for the same effect.

This last example illustrates yet again the inadequacy of nonnuclear testing and the need for nuclear tests. Without the low-temperature nuclear test, the weapons designers would have judged, on the basis of the nonnuclear tests, that the system would perform properly. However, in actuality, the deterrent capability of this particular weapon system would have been jeopardized under environmental conditions that could have been fully expected to occur. As a result of the experience with this particular warhead, similar low-temperature nuclear tests have been done for several other weapon systems.

It is inevitable that future stockpile problems will occur. Weapon scientists cannot address the impact of new technologies, verify that a problem has been properly fixed, or certify that a new weapon design will meets its military requirements on the basis of nonnuclear experiments alone. Nor can they model with computers all the complex physical processes necessary to predict with confidence warhead performance and warhead vulnerability.

Assessment of weapon performance rests on scientific judgment based on nuclear test experience. This judgment takes considerable time to develop. It is cultivated by the application of theory and experiment to device design, and it is continually refined on the basis of data from nuclear tests. Removing the confirmation provided by tests would result in the overextension of judgment and in the reduced credibility of the nation's deterrent. This was indeed the case (Reference 2) from 1958-1961 when the U.S. and U.S.S.R. observed a moratorium on nuclear tests. The U.S. experienced a number of surprises when certain weapons developed during the moratorium failed to perform as predicted when they were finally tested.

One of the real concerns about a test ban is that after a number of years, U.S.S.R. scientists might recognize a breakthrough and break out of the treaty. U.S. achievement of the same breakthrough would be much less likely because many U.S. weapons designers would leave the weapons program in a free society.

3. Stockpile Modernization

The directions and emphasis of the U.S. modernization program have often been poorly understood. Contrary to popular belief, the so-called "arms race" has led to a reduction in the numbers of U.S. nuclear weapons by nearly 25 percent and in the total destructive yield by a factor of four, while simultaneously maintaining adequate security for our country. This reduction would not have been possible without nuclear testing. Of more importance, however, the primary focus of U.S. modernization is on the enhanced safety, security, and survivability of our nuclear deterrent forces.

Few would argue that as long as we have nuclear weapons, they should be safe and secure. Yet a ban on nuclear testing could preclude needed changes to the stockpile in these important areas. While there have been no nuclear accidents involving the U.S. stockpile, there have been accidents which have involved the detonation of high explosive and dispersal of radioactive plutonium across the countryside. These accidents contributed to a policy which prohibits aircraft on airborne alert from carrying nuclear weapons. On the ground, aircraft are more susceptible to surprise attack. We have now developed a new high explosive, called insensitive high explosive (IHE), which would not have detonated in these accidents. The U.S. has begun to deploy IHE in stockpiled weapons, but this replacement is only one-third complete. Because IHE performs much differently than past explosives, weapons using it must be redesigned and tested. Thus, the imposition of very restrictive test limits would preclude putting IHE into the rest of the stockpile.

The global strategic balance is a dynamic, not a static situation. Developments in non-nuclear areas such as ICBM accuracy, antisubmarine warfare, and aircraft defense can influence the need for new, survivable weapon systems. An example of the need to improve survivability of our land-based missiles is the considered deployment of a small mobile ICBM, the SICBM, or Midgetman. The cost effectiveness, weapon size, weight, degree of mobility, acceptable environments, and number of warheads for the SICBM is currently being debated. Depending on the final warhead design, the viability of the system could be compromised by a test ban.

4. Nuclear Effects Testing

A very important part of our nuclear testing program is testing the effects of nuclear weapons on a vast array of military equipment. Of particular importance are the non-nuclear components of our strategic weapon systems, warning sensors, and communications equipment which might have to work in a nuclear environment. If deterrence is to work, our forces must not present a vulnerable target to the Soviets encouraging them to take advantage of us in a crisis. As in the testing of basic weapons themselves, we are frequently surprised by the results of effects testing on equipment which has previously undergone nonnuclear testing. Changes and subsequent nuclear testing are required to certify that these important elements of our deterrent system will be able to function properly during a crisis. The head of the Defense Nuclear Agency should testify further on this subject.

5. Avoiding Technological Surprise

Under restrictive nuclear test limitations, U.S. options for responding to an evolving Soviet threat would be severely constrained. We know that the Soviets have been actively doing research on defensive systems for a number of years. There are estimates that they have been outspending us in the defensive area by almost an order of magnitude. Improvements in their air defenses have already eroded the penetrability of our bombers and they continue to make progress in this area. They have been active in anti-ballistic missile system research, including directed energy weapons. Breakthroughs in these areas could threaten the penetrability of our missile warheads in a retaliatory strike. Improvements in anti-submarine warfare capability would threaten the future survivability of our submarines. Further Soviet development and deployment in ASATs would threaten the survivability of our C^3I (command, control, communications, and intelligence) assets. Further improvements in the accuracy of their ICBMs, including the use of satellites for ultra-accurate terminal guidance, would threaten the survivability of our land-based ICBMs. Most of these likely Soviet developments are nonnuclear in nature, but our ability to react to them may require changes in our nuclear technology. We may need new delivery systems which will require new warheads and nuclear testing will be necessary for their development.

There may also be Soviet developments in the nuclear area that we are not aware of. We know they have actively done research on the x-ray laser but we do not know if they have developed an x-ray laser weapon.

A key factor in avoiding technological surprise is the maintenance of competent weapon scientists with the necessary scientific judgment to evaluate what technological developments by our adversaries threaten the viability of our nuclear deterrent. Furthermore, if the Soviets break out of a test limitation treaty, or try to evade it, we must have personnel with the necessary skills to respond.

6. Factors that Determine a Weapon Design

It has been argued that nuclear weapons can be designed to be more robust to the effects of aging and changes in deployment scenarios. However, it must be recognized, that in specifying the requirements for new nuclear warheads, the Department of Defense (DOD) prepares a set of military characteristics (MCs) that define the requirements. These requirements include, first and foremost, nuclear safety, followed by size and weight to achieve a design yield. A consistent feature of U.S. deterrent systems has been small, compact warheads tightly integrated to smaller missiles and submarines. Since nuclear warheads cost roughly 10-15% of the total system costs, this is the most cost effective approach.

The weapons in the stockpile and currently under development have been designed to be as conservative as possible with respect to the adverse effects of aging within the requirements of the MCs. Correcting a problem in the stockpile is expensive and time-consuming. The need for such actions is minimized by taking appropriate care when a weapon is designed and before it enters the stockpile. Scientists and engineers strive to make their designs durable and robust against all foreseeable stockpile conditions. Even so, situations have arisen with stockpiled weapons that have brought into question their continued endurance and reliability. Nuclear tests have been required to identify and, in a large number of cases, to resolve these problems.

If stockpile endurance were the highest priority, U.S. warhead designs would have been different. The warheads would be larger and heavier and would have contained more nuclear material. We might also have forgone many stockpile improvement features involving enhanced safety and security that tend to increase warhead sensitivity to stockpile aging. Changes in priorities could have led to very different military systems-missiles or other platforms with different throwweights, ranges, accuracies, and operational flexibility. In addition, the economic impact of a different set of priorities would have been substantial.

7. The Impacts of TTBT on American and Soviet Programs

We can meet our current military requirements and do weapons physics research that we deem to be appropriate and necessary within the 150 kt limit. The design constraints on the U.S. nuclear weapon program resulting from the 150 kt threshold have been acceptable to date. However, if the military requirements arise for development of a very high-yield RV or a high yield earth penetrator weapon to attack deeply buried or strongly hardened targets, we might not be able to develop such weapons under the 150 kt limit, and a few tests at 300 kt could be very useful.

Factors other than the impact upon the weapon development program must also be considered. We perceive that significant assymmetries could develop if the present threshold were removed. Because of ground motion in Las Vegas resulting from nuclear explosions at NTS, we would be limited to explosions of less than 800-900 kt. It would be difficult to go to other sites, say Amchitka, for reasons of cost and political acceptability. Prior to the TTBT, the Soviets tested to several megatons at their Novaya Zemlya test site, a site they continue to use. Because of the isolated nature of that site, we cannot rule out the possibility that they could resume at yields even higher than before, if a TTBT were not in force. Without a TTBT, the Soviets would thus have an advantage in the size of explosions they could conduct. The advantages of increasing test yields from 150 kt to a number of megatons could be very significant. Hence, the 150 kt yield limit has an advantage over a no-limit on yield treaty because it prevents a technically significant asymmetry in testing capability between the U.S. and the Soviets. I must emphasize, however, that if military requirements arise for new weapons with yields substantially above 150 kt, it would be difficult, if not impossible, to develop such weapons within the current TTBT limit.

8. Significance of Possible Soviet Violations of the TTBT

The nuclear design advantages of increasing test yields from 150 kt to 300 kt would not have been very significant from my viewpoint of U.S. experience. A yield of 300 kt is within the approximate factor of two uncertainty range of current official yield estimates. (I address TTBT verification and compliance issues in Sections 9.1-9.3.) In assessing what is significant to the Soviets, we are forced to use a "mirror image" or similarity approach because we know little about their design practices. Just prior to the TTBT in 1976, we obtained enough data from high-yield U.S. tests to permit us later on to certify the yields of new strategic systems such as the MX and Trident II warheads and the B83 bomb. For purposes of assessing the current Soviet threat, we normally assume that they did similar high-yield tests prior to the TTBT. We conclude that if they did do the appropriate tests before 1976, there may be no major significance to the few tests which the Soviets might have conducted between 150 kt and 300 kt after 1976. If, on the other hand, the Soviets did not conduct the necessary tests prior to 1976, there may be some advantage and motivation for them to do so now. Cheating on the TTBT limit could provide more benefit if they were developing new weapons in the several hundreds of kiloton to megaton range.

While ratification of the TTBT would preserve the status quo at 150 kt (a potential advantage over a no-yield limit treaty in view of the asymmetries that exist between us and the Soviets in terms of the yields that can be safely achieved at our respective test sites), the preamble to the treaty calls for the discontinuance of all test explosions of nuclear weapons for all time. Such discontinuance is inconsistent with the context of the Strategic Arms Reduction Talks and arms reduction with modernization. This represents a serious concern that I have with the TTBT. The President's current proposal is the right approach.

9. Verification of Test Restrictions

Verification of compliance with nuclear test limitation treaties involves a complex mix of disciplines. Seismology currently forms the basis for the monitoring technology and hydrodynamic yield measurements have been proposed for improved monitoring. Statistical tests of the compliance hypotheses form the quantitative part of the decision making process. Ultimately, value judgments must be made about the relative importance of identifying militarily significant violations versus limiting the number of false accusations. The goal is to deter a potential evader. Improvements are needed in the application of all disciplines, but I will focus on the monitoring aspects.

9.1 Limitations of TTBT Monitoring

Monitoring compliance with the TTBT is currently done by teleseismic means. Using its own seismic network, each nation determines the seismic magnitude of the other's explosions and then, by use of a yield-magnitude relation, estimates the yield. Successful evaluation of compliance with the 150 kt yield limit using seismic data hinges on two issues: 1) what is the correct relationship between seismic magnitude and yield for the Soviet test sites, and 2) how should we treat the variations in the seismic coupling, propagation, and recording processes that introduce random errors in the seismic magnitude measurements.

With regard to the first issue, a magnitude-yield relationship has been developed for explosions at the Nevada Test Site. However, virtually all seismic studies have shown that, because of geological differences, the relationship is different for the Soviet test sites by an amount known as the "bias". Because the effect of the bias is to shift the entire body of Soviet yield estimates to lower values, the assumed value of the bias has a major impact on one's view of the question of Soviet compliance with the yield threshold. Ultimately, it could affect one's view of the configuration of the Soviet arsenal.

With regard to the second issue, the random variations in the seismic data can make the estimated yield of any explosion appear to be either smaller or larger than its actual yield, even if the bias is known. For example, given a series of explosions with actual yields of 150 kt, half of them on the average will have estimated yields greater than 150 kt, and half smaller. Thus, the issue of compliance must be dealt with in a statistical framework. In general, the procedures which we use allow us to calculate the probability of obtaining an estimated yield as large or larger than the one which is observed if the true yield was less than the threshold. If this probability is small, we reject the compliance hypothesis.

9.2 Soviet Compliance with the TTBT

Based on our own assessment of the relationship between yields and seismic magnitudes for the Soviet test sites and the patterns of Soviet testing, we have concluded that the Soviets appear to be observing some yield limit. Livermore's best estimate of this yield limit, based on a probabilistic assessment, is that it is consistent with TTBT compliance. However, because of the statistical uncertainty of teleseismic yield estimates and the uncertainty in extrapolating U.S. experience to Soviet test sites, we cannot rule out the possibility that a few Soviet tests may have exceeded the limit. Based on the technical factors that I have discussed above, I believe that it is impossible to state with certainty that the Soviets have or have not violated the TTBT.

The policy experts must weigh the evidence and decide whether a charge of noncompliance is warranted and whether such noncompliance is a serious breech of the treaty, given the technical issues, the uncertainties, and the assumptions. There are those who believe that any violation of a treaty is a serious matter. In regard to the TTBT, one must keep in mind that we and the Soviets did come to a common understanding that "one or two slight, unintended breaches per year would not be considered a violation of the Treaty." However, we did agree that such breaches would be a matter of concern.

9.3 Improvements in TTBT Verification

Although in the past, our assessments of Soviet compliance do not seem to indicate violations of serious significance, the accuracy of the present yield estimation methods is such that in the future we may not be able to distinguish confidently between compliance and potential violations that we would consider to be significant. For this reason we need to improve our monitoring capability.

The TTBT contains a number of provisions which have never been implemented because the treaty has never been ratified. These provisions include the exchange of information about test site geography and geology and the yields of two calibration explosions for each geophysically distinct area within the test sites. While calibration yields provided by the Soviets under the existing TTBT provisions could not be corroborated, quantitative data on the geological and geophysical properties of Soviet test sites would be useful. We already have a significant body of data on the general characteristics of Soviet test sites and it would be difficult for the Soviets to falsify such data in a useful way. The additional detail that would result from carrying out the exchange of geological and geographical data would improve our general understanding of their test sites. However, the improvement would be qualitative rather than quantitative.

Hydrodynamic yield measurements similar to those provided for in the PNET, could be useful in reducing the uncertainty in yield determination. In order to carry out these measurements on nuclear weapons tests, which typically have many diagnostic experiments of a sensitive classified nature in the emplacement hole, it is proposed to carry out these hydrodynamic yield measurements in a satellite hole near the emplacement hole. Use of a satellite hole also improves the accuracy of the yield determination. It has been estimated that the uncertainty in such a hydrodynamic yield measurement is 30% or better if some restrictions are placed on the experimental configurations of the canisters that contain the nuclear device and on the diagnostic equipment.

The presence of Soviet personnel at the Nevada Test Site would also pose operational security problems. In general, these could be handled at some increase in cost. The problems would, however, be exacerbated for nuclear directed energy weapons tests which have unique geometric arrangements. Inspection of the canisters of these tests to verify that treaty restrictions were being followed could reveal sensitive design information unless special procedures are followed.

It has been proposed that several seismic stations located at the Soviet test site near Semipalatinsk would be useful to better understand the seismic transmission characteristics of that region of the Soviet Union. It has been argued that calibration of the test site at Semipalatinsk might be derived by comparing signals (from any seismic source elsewhere in the world) detected at such stations with those detected at existing teleseismic stations. However, the calibration would not be as good as that obtainable from CORRTEX measurements and important information about the way explosion energy is coupled into the ground would not be available. The benefits of this proposal are not yet well quantified and appear to be more qualitative than quantitative at this time.

9.4 Verification Adequacy of the PNET

The Soviets have executed peaceful nuclear explosions (PNEs) at sites scattered throughout their country. The properties of the seismic wave propagation beneath these sites can vary significantly, but the PNE treaty does not provide a means to calibrate the seismic measurements for this effect. As a result, yield estimates for PNE explosions with nominal yields close to, but less than 150 kt will have larger uncertainties than the yields for explosions at the weapon test sites at Semipalatinsk and Novaya Zemlya. (Group explosions with aggregate yields greater than 150 kt allow the deployment of U.S. equipment for hydrodynamic yields to obtain an independent estimate of the yield of each device.) Therefore, under the terms of the present PNET, there is the potential for an occasional militarily significant violation. In the past, the estimated yields of PNE explosions since 1976 have been significantly less than the 150 kt limit and this has not been an issue in practice.

Other factors constrain the execution of a sustained program of significant TTBT violations under the guise that they are PNEs. 1) The yield of the device must be consistent with the purpose of the experiment. 2) The observed effects of the explosion must be consistent with the nominal yield. For example, higher yields have often been associated with cratering events, which have observable surface effects.

The data exchange provided for in the PNET protocol would provide valuable information about each Soviet PNE explosion. Such a data base would significantly improve our understanding of the geophysical properties of the Soviet Union. For example, pre-knowledge of the locations, yields, and times of their past 50 PNE explosions would have provided valuable opportunities to focus various National Technical Means (NTMs) on these events to study such aspects as detection thresholds and seismic signal propagation in the USSR.

The PNET also would establish a Joint Consultative Commission to implement the data exchange and to resolve questions regarding each country's actions with regard to the PNET. Such a forum could be a valuable channel for exchange of technical data and compliance questions for the TTBT as well.

9.5 Improvements in PNET Provisions

The primary improvements that can be suggested for the PNET consist of implementing the various existing provisions, but at lower thresholds than are now the case. With these provisions, the military benefits that might be derived from evasion attempts under the PNET will be reduced and be made comparable to that of the TTBT.

Conclusion

For the foreseeable future, safe, secure, reliable, survivable and effective nuclear weapons will be a critical element in the stability of the strategic balance and the security of this nation. The existence of these weapons reflects the reality of the tension which exists between the United States and the Soviet Union. Nuclear test bans will decrease the viability of this element of our national security. A serious question that must be asked is how our national security will be enhanced by more restrictive test limitation. Their immediate impact seems to me to be primarily symbolic and they do not address what I believe are the most important issues: major reductions in strategic and conventional forces and a general lessening of the tension between the two countries. In fact, some believe that the diversion of political effort from the more important issues and the tensions generated by test ban verification problems will, in the long term, decrease the safety of both countries.

I believe that a nuclear test ban, or more restrictive test limitations, should only be considered in the context of an integrated and comprehensive approach to arms control. A CTB may be the correct last step in our quest for nuclear arms control and a stable peace, but it would be a disastrous first step. In my opinion, further testing limitations will better serve the goals of increased stability and decreased tension only if they are instituted after major progress has been made in reductions in strategic and conventional forces.

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Prepared Statement of Dr. Siegfried S. Hecker

I welcome the opportunity to present to this Committee certain technical aspects of the Threshold Test Ban Treaty (TTBT), the Peaceful Nuclear Explosions Treaty (PNET), and the issue of improved verification. On balance, it is my view that ratification of the treaties is in the overall national interest of the United States, provided that verification of Soviet compliance is improved in the manner proposed by the President.

In presenting my views as Director of the Los Alamos National Laboratory, I want to reiterate the role that the weapons laboratories play in the nuclear weapons program. The DOE has statutory responsibility to design and develop nuclear weapons that are determined by policy makers to be necessary to assure this nation's deterrent. The job of meeting this responsibility is assigned to the two DOE weapons laboratories, Los Alamos National Laboratory and Lawrence Livermore National Laboratory. We are also responsible for the safety, security, production oversight, surveillance and retirement of nuclear weapons. I personally have the final responsibility for certifying the weapons we design. This certification holds for both the performance and the safety of the weapons during their entire life cycle. A major additional part of my job is to guard constantly against technological surprise, primarily by potential adversaries but also by our own products, the nuclear weapons in stockpile.

Nuclear design responsibility for U.S. nuclear weapons rests strictly with the two weapons laboratories. Nuclear testing continues to be an indispensable part of the design process because of the great complexities of nuclear weapons behavior, which cannot be completely modeled by computer nor adequately explored by non-nuclear laboratory experiments. As long as requirements for nuclear deterrence are dynamic and we continue to be asked to satisfy new military requirements, or to be responsible for weapons already part of the deterrent forces, we will need nuclear tests. Restrictions, including the present ones, on our ability to test these complex devices carry technological risks. These technological risks may translate into military risks, or at least military penalties. I consider it my responsibility to bring these technological risks to your attention. You and other policy makers must judge the trade-off between these risks and any benefits resulting from such restrictions.

Before the summer months arrive, we will have had eleven years of strict compliance with the 150 kiloton (kt) limit imposed by the TTBT on our nuclear test program. I shall outline our experience during this period. An important aspect of that experience, particularly since 1977 when the last hearings on these treaties were held by this committee, has been a significant change in military requirements for new weapons with yields well above the 150 kt limit. These requirements have resulted primarily from Soviet actions in the past decade. As a result, they were not reflected in the earlier testimony on the treaties now under review.

I am sure that the Committee is aware that both the total megatonnage and the number of weapons in the U.S. nuclear arsenal have declined significantly during the past two decades, the first by a factor of four and the second by one-third. It follows that the average weapon yield today is well under half what it was in the mid-60s. This trend in part reflected a major shift to MIRV technology in our strategic forces.

In 1974-77, the Soviets were beginning to explore MIRV technology themselves. For several years it was hoped that the Soviets would exercise restraint in deployments of the new MIRVed missiles, which because of the large Soviet payload capability would have a significant counterforce potential in large numbers. By the end of the last decade, it was clear that both the size of the Soviet threat and the greatly increased hardness of Soviet silos and other important military and political assets posed a fundamentally new problem. A strategic nuclear targeting review culminated in the Carter Administration's PD-59 directive, followed shortly by the present Administration's NSDD-13 directive. Both directives, among other important changes, called for improved U.S. capability against hardened military targets. This action affected the yield requirements for both the planned MX Peacekeeper missile and the Trident D5. In the TTBT environment, this clearly created a problem for the weapons laboratories.

We were able to respond to the new requirements, and to others that arose in the same period, because of advanced development testing done before the TTBT limit became effective. A test of the greatest importance to this response, in fact, was done as early as 1973. Others were done as late as

Spring, 1976, in anticipation of possible future requirements that could not be met under the 150 kt limit. Thus, because of this inventory of tested assets, we were able to meet requirements for new high-yield weapons despite the restriction on testing. It may be more difficult to meet foreseeable future requirements under the TTBT constraints.

Let me now describe in more detail the effect that strict compliance with the 150 kt limit has had on our test program and on our ability to meet our responsibilities. First, a number of tests were precluded by the TTBT limit that almost certainly would have been done otherwise. Among these were full-yield tests of new or modified high-yield designs based on older tested technology, as well as full-yield stockpile confidence tests. In addition, tests of new design concepts that may become important in the future could not be done. We have exploited our reserve of older tested technology, and we have been unable to replenish and extend it as we did in anticipation of the threshold limit.

When we examine the nuclear tests that still were permissible over the ten year period following March 31 1976, we find that a significant fraction of them were affected by the yield limit. We also find that the tests affected were among the most important. They include more than one-fourth of the stockpile-confidence tests during this period and about one-eighth of the tests in the categories of weapon development and advanced design technology. These three categories together made up over half of the total for both laboratories, and they were the ones that most directly supported DoD requirements for new weapons and for weapons with improved safety and security. The TTBT constraint limited the value of the tests in question.

In spite of this, and for the reasons I have outlined above, we have been able thus far to meet the nation's military needs. It is important, however, to repeat the caution voiced during the 1977 hearings by one of my predecessors as Director of Los Alamos, Harold Agnew:

> ....if you believe that there will be requirements for new untested designs of yields considerably larger than 150 kt, then, if the treaty is ratified, our defense systems eventually will have to bear a penalty in payload weight, physical size, and perhaps even in the additional use of fissile materials. These penalties will accrue because under the treaty the high-yield warheads of the future will of necessity be the same ones which have been developed in the past.

To a significant extent, Agnew's prophecy has been fullfilled, although the penalties thus far have been manageable.

The basis for weapon certifications by the laboratories has changed in a significant way from that of earlier years, when judgments could be more directly tied to full-yield tests of at least near-weaponized devices. It now rests heavily on indirect evidence obtained in partial-yield tests, interpreted by skilled designers. The element of risk in this process obviously increases as the basis in test data is reduced. (However, the moratorium of 1958-61 demonstrated that new military requirements continue to arise, and higher risks are accepted, when testing is completely suspended.)

One result of this change has been increased emphasis on stockpile confidence testing, although, as I already have noted, a significant number of these tests have themselves been adversely affected by the treaty limit on yield. In the past, such tests have been essential in certain cases to assess the effects of prolonged exposure to the stockpile environment (such as aging) on a weapon, or to answer other reliability questions that may have been raised in the course of the on-going test program. In other equally important cases they have served to confirm the validity of the many practical decisions made during the translation of a tested physics design into an actual stockpile weapon. It is no longer possible, however, to test a warhead's full performance when the intended yield of the weapon lies above the TTBT limit. In such cases, which include the most important designs we have added to the stockpile since 1977, the weapon must be modified from its stockpile configuration before testing. What is tested, therefore, is not what is in stockpile.

These facts tend to increase the already great reliance we must place on the judgments of experienced designers. Their judgments are informed chiefly by current and older test results pertaining to the specific systems involved, but the relevant test experience is receding into the distant past.

This last point becomes a serious concern mainly as I look toward the future. In recent years, we have relied heavily on components of a few older tested designs, and it is probable that some other requirements, should they arise, can be met in the same way, with increasing penalties. It is evident, however, that the test experience on which new adaptations of these older designs is based is being eroded by time. Some of the key individuals involved in their development already have retired or gone on to other work.

The link with direct test experience in the high-yield range thus is becoming increasingly tenuous. This fact, of course, creates the imperative that we resist any deviations from that experience as we adapt it to new requirements, but the resulting conservative policy inevitably leads to the penalties predicted by Agnew.

Finally, it is becoming clear that certain weapon requirements now under study by the DoD and the DOE laboratories may well prove to be beyond the reach of the older tested design technologies. As I have noted already, these requirements are determined in most cases by the changing nature of the targets (e.g., hardened, dispersed, relocatable) that must be held at risk if stable deterrence is to continue. They are augmented, however, by our continuing concerns regarding weapon safety and security and our continuing emphasis on improved command and control. While I am optimistic about our ability to respond to some of these needs under the TTBT constraints, it must be recognized that success cannot be guaranteed in all cases.

To summarize, we have been able thus far to meet our responsibilities to contribute to the nation's deterrent under the testing limit imposed by the TTBT, even though the requirements that have had to be met for new high-yield weapons have exceeded those explicitly foreseen in 1974 and 1977. We have met our responsibilities only by using old, previously-tested designs. I should point out to the Committee that this statement of having met responsibilities would not be possible today if the yield limit for tests had been significantly lower during the past decade, nor, I believe, will it be possible a decade hence if increased restrictions are invoked, unless there has been a fundamental change in the requirements for nuclear deterrence.

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Let me turn now to the question of verification. Much of what is new since 1977 with regard to the treaties under consideration lies in this area. As I said at the beginning of this statement, I fully support the President's decision to make the agreement on improved verification measures a condition for their ratification. My purpose here is to give to this Committee a brief outline of the technical basis for my own belief that verification must be improved if the benefits of these treaties are to be realized.

I would consider verification of compliance with these treaties to be effective and adequate if neither side can obtain a significant military advantage through clandestine violations that cannot be overcome by the other side without violating the treaties. At present, verification of the TTBT does not meet this standard, nor would it following ratification unless essential changes are made in its provisions.

The record clearly shows that verification concerns played a significant role during negotiation of the TTBT in 1974, and an even greater role in the subsequent PNET negotiations during the next 18 months. They also were the focus of much of the testimony in 1977, which was uniformly optimistic that the problem of verification was well in hand. Subsequent events and the experience of the last decade have changed this picture considerably.

The point I wish to emphasize most strongly is that the current debate over past Soviet compliance or noncompliance is not the main verification issue that should be considered in the ratification debate. Instead the fundamental issue is how can we effectively verify compliance in the future? You will, I am sure, hear arguments on both sides of the question of past Soviet compliance. Usually these arguments revolve around the question of the proper bias to apply to our teleseismic interpretations of signals from Soviet tests. But it is important to understand that changing the bias, as has been done several times in the past, can only shift inconclusive evidence slightly in favor of a verdict of compliance or slightly in favor of noncompliance. The evidence still will be inconclusive, because of the inherent statistical uncertainty in teleseismic yield estimation.

The event most often cited in recent discussions of concern about TTBT verification is an abrupt upward change in the observed pattern of seismic signals coming from the Soviet test site at Semipalatinsk. This jump was unforeseen at the time of the 1977 hearings. It occurred about a year after a comparable downward adjustment in our way of estimating yields from the seismic signals. Before the change was made, several 1976-78 tests appeared to be violations, but with the new "bias correction" this no longer was true. The present concern, however, results from Soviet tests after the bias change. The new troublesome pattern continued until the Soviets suspended their test activities last year. There has been a great deal of debate about the significance of this test pattern and whether or not it proves Soviet noncompliance with the TTBT limit.

The view of my colleagues who have worked hard on this problem is that the only conclusion possible is that reflected in the old Scotch verdict: Guilt not proven. But neither is innocence, which is what verification requires. The pattern of Soviet testing is consistent both with substantial (that is, approximate) compliance, especially after the most recent revision downward of our official yield estimates, but it also is consistent with militarily significant violations. There is no marginal further change in seismic interpretation that can shift the weight of evidence decisively one way or the other, in my view.

Thus the essence of the verification question now before this Committee is not whether the Soviets have violated the limit in the past but rather the fact that, unless changes are made, I believe they will have the ability to do so in the future. The key issues, of course, involve the questions what is a militarily significant violation, and what changes are required?

With regard to the first of these, a most important technical change has occurred since 1974 and the earlier hearings in 1977. There has been steady evolution and vigorous deployment of new Soviet strategic weapons, the most threatening of which now consist almost entirely of exceedingly accurate MIRVs, an evolution that could not have been predicted reliably in 1974. At the time of negotiation of the TTBT, most Soviet missiles carried large single warheads in the several-megaton range. Our MIRVs were balanced against this Soviet force of much greater throw-weight to establish essential equivalence, or parity. The optimism that the Soviets would exercise restraint in MIRV deployments was proved wrong. Modernization of Soviet forces has threatened the rough parity of 1972. The present Soviet MIRV weapons have much smaller yields than those of the weapons deployed in 1974, increasing the significance of smaller violations of the TTBT limit.

It could reasonably have been argued in 1974 that, with Soviet strategic weapons in the range of several megatons yield, violations of the 150 kt limit by factors of two to three would be of little military significance. At least one government study at the time concluded that the Soviets could test at two or more times the 150 kt limit, but this evidently was judged to be relatively unimportant then. We know now, as a result of our analysis of the statistics involved, that the problem is even worse than the 1974 study suggested; the experience of the past decade confirms our conclusion that a seismic yield estimate would have to be well above twice the threshold limit before a substantive response was likely to result. But with the majority of Soviet ICBM yields now in the 500 kt range, a violation at the 300 to 450 kt level can no longer be dismissed as having little military significance. This is particularly true at a time when changes in the targets we must hold at risk may require entirely new, untested designs in the same yield range.

The ability to conduct such tests, at least occasionally, cannot be denied the Soviets under the present treaty provisions, even after the exchange of data that will follow ratification. On the other hand, the U.S. has scrupulously complied with the 150 kt limit. Since both sides have strategic weapons requirements well in excess of this limit, violation of the limit by the Soviets could create an asymmetry that has significant military implications. Even the most confident resolution of such questions as the correct value of teleseismic bias between test sites cannot alter the fact that future Soviet compliance cannot reliably be assured by national technical means alone, even if these are "calibrated," as some have proposed. To provide assurance of compliance at yields much closer to the treaty limit requires the negotiation of additional verification measures having the capability of those proposed to the Soviets by the President. Without such measures, there can be no assurance that militarily significant violations of the limit are precluded in the future.

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I would like to briefly discuss the work we have been doing at Los Alamos to support the President's decision to seek improved verification of compliance with the TTBT limit.

The U.S. has proposed to the Soviets to have on-site observation by each country of tests by the other that are expected to be in a yield range where compliance questions might reasonably be anticipated. Thus there would be a lower limit below which such observations would not be necessary; in my view this limit must be chosen rather carefully in order to provide effective verification without unduly impinging on the test activities of either side.

The proposed observations would consist of on-site measurements of the position of the rapidly expanding shock wave that is produced by the nuclear explosion. The result of the measurement and its interpretation is called the "hydrodynamic yield" of the explosion. Under certain conditions, the yield can be inferred very accurately from such measurements, e.g., CORRTEX; those conditions are well-understood, and, of course, they must be provided for in Protocol language that is drafted with great care.

There is a very long history of successful U.S. underground yield measurement by this method, over the entire yield range from sub-kiloton to Megaton, in simple as well as extremely complex test configurations, and in the particular geometry proposed for weapons test yield verification measurements. We believe it is thoroughly understood and already used in some form by the Soviets. Moreover, this same method was the basis of the successful negotiations in 1974-1976 that resulted in the very elaborate verification Protocol to the PNET that this Committee now has before it.

This elaborate Protocol makes the PNET, with small changes as may be required if the TTBT verification is improved, effectively verifiable. However, I must caution that this is true only if the TTBT threshold remains 150 kt. If there are further restrictions on weapon test yields, the permitted PNE yields must be correspondingly lowered. Otherwise, even a perfectly legitimate peaceful explosion can be used to obtain military benefits unobtainable in a weapons test.

The problem we have been working on for several years at Los Alamos is that of applying the on-site hydrodynamic technique to the limited objective of weapons test verification under the 150 kt limit. It goes without saying that there are important new problems that arise when weapons tests, rather than explosions for peaceful purposes, are the subjects of such observations. We must not interfere with the test objectives of either side; some of the provisions in the PNET Protocol would do so. Neither can we allow the slightest compromise of sensitive classified information. This was a concern also for the PNET, but the problem was more easily solved. Finally, we must devise a plan that effectively protects us from being "spoofed," even in complex test geometries that were precluded under the terms of the PNET. It is my belief that our work at Los Alamos has dealt successfully with all of these problems, and we now have acquired a sufficient data base through experiments conducted on our own test program to provide very high confidence that the verification objective can be achieved without compromise of secret information and without significant danger of spoofing.

To accomplish the verification objective, we have developed at Los Alamos, and thoroughly tested, a new generation of equipment that is much more capable and easily used than that which was available in 1976. I should stress, however, that the essential element in the President's verification proposal is the on-site measurement of hydrodynamic shock position, rather than the specific equipment to be employed. While we are justifiably proud of our CORRTEX equipment, it is entirely possible that other equally capable or even better devices will become available.

I should add that we have thoroughly evaluated the verification capability that will result from employment of these measurements to solve the TTBT problem. The key questions are: what is the yield at which the Soviets can test both routinely and occasionally if this method is employed, and what is the military significance of tests at those yields? The same questions, I believe, must be answered quantitatively for any proposed alternative. The method I have discussed fully meets the requirement for effective verification that I defined earlier in this statement.

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In summary, I favor ratification of the TTBT and PNET with the provision of improved verification. The United States should insist on a verification protocol that does not allow the Soviets to test at a level above the threshold limit at which they can achieve a militarily significant advantage. It is important to note that all testing restrictions lead to technical risks and potential military penalties. The TTBT restrictions to date have been manageable, but there is concern about the future. Testing constraints more restrictive than those in the TTBT would greatly endanger our ability to adequately support the Nation's deterrent in terms of safe, secure, reliable and effective nuclear weapons.

Prepared Statement of William E. Colby

Mr. Chairman, thank you for this opportunity to testify on the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty, and especially the verification implications thereof. Let me first say that I thoroughly endorse the ratification of these two treaties. I do not claim that they are the ultimate answer to our problems with the Soviet Union, nor even that they represent a breakthrough arms control measure in the context of the current nuclear competition. But they do make a very important contribution to our national security, and also constitute an important step in the direction of further arms limitations. Following this ratification I would hope that we could proceed with negotiations toward a Comprehensive Test Ban Treaty while taking advantage of the apparent Soviet willingness to negotiate deep reductions in existing offensive weapons.

As a basis for discussing the verifiability of these two treaties, I think it important to have a clear understanding of the purpose of verification. It is not to give us evidence to use in a court of law against the Soviets, but rather to protect our country against surprise. Seen in that context, it is obvious that the United States will monitor, or "verify," Soviet nuclear weapons developments whether we have a treaty between us or not. The normal uses of our intelligence systems are particularly addressed to determining the degree of threat that Soviet nuclear forces might present to the United States. And I might add that these services do an extremely good job. This can be seen, among other ways, in the Defense Department's annual publication on the Soviet military, which gives detailed descriptions of various weapons systems and forces, many of which are considered by the Soviets to be highly secret.

With respect to nuclear explosions, the full provisions of these two treaties make this process easier rather than more difficult. This is accomplished through the requirements of the Threshold Test Ban Treaty for exchange of data, through limiting these tests to specific sites, and through the Peaceful Nuclear Explosions Treaty's provision for inspection teams to attend explosions which approach the threshold. The provisions in the Peaceful Nuclear Explosions Treaty for discussion in a Joint Consultative Commission of any problems arising in the interpretation of, or compliance with, the treaty further assist in clarifying the nature of Soviet activities. Thus it can be clearly said that the treaties will expose more of Soviet activities than would be the case in their absence.

There have also been many scientific developments since these treaties were signed that very distinctly assist the verification process. Some of these advances are due to improved seismographs and other monitoring technologies, which give us better raw data. Other advances result from better analysis of that data through improved understanding of seismic behavior. For example, we are much better at distinguishing earthquakes from explosions than we were a decade ago, as we are at distinguishing among different types of seismic waves. These advances now provide our scientists with confidence that nuclear explosions as small as ten kilotons or lower can be identified, even from sites outside the Soviet Union.

The 1984 completion of a sensitive seismic array in Norway further improved our monitoring capabilities over what they were when the treaties were signed. And the recent arrangement by the Natural Resources Defense Council to place a monitoring team within the Soviet Union will provide us with significant calibration data and a better knowledge of the geology of that area, even though their scientists have not been able to measure an actual nuclear test because of the Soviets' nearly eighteen-month old unilateral moratorium. And there have also been developments within the Administration and the intelligence agencies through which we have improved our basis for calculating Soviet test yields by better understanding the geological differences between the Soviet's Central Asian test site and our Nevada test site.

Incidentally, this long-overdue correction in our estimates of Soviet test yields points up these treaties' direct contribution to our national security. For example, it now appears that the yields of many deployed Soviet strategic warheads are lower than previously thought. According to some scientists, this indicates that over the past decade the Threshold Test Ban Treaty has effectively constrained the Soviets from developing higher-yield and more efficient warheads. We also now know that it is unlikely that the Soviets have been intentionally violating the Threshold Test Ban Treaty, contrary to the charges raised by the Administration. This should further boost our confidence as we consider ratification of the Treaties.

Unfortunately, the matter of ratification is in danger of stalling over questions of verification technology. This dispute revolves around the so-called CORRTEX system. CORRTEX requires the on-site emplacement of sensors. Depending on how the Administration seeks to employ it, at a minimum CORRTEX would be utilized for several calibration purposes tests, or at a maximum for every Soviet test over a certain yield. On-site inspection of nuclear testing was not included in the Threshold Test Ban Treaty, though the Soviets did agree to some on-site inspection in the Peaceful Nuclear Explosions Treaty and have accepted that in-country monitoring must be part of a comprehensive test ban.

Clearly there remain strong disagreements among American officials as to just how to apply the CORRTEX system and other monitoring techniques. Unfortunately, these disputes are obscuring the central point: *we already possess means of verifying the Threshold Test Ban and Peaceful Nuclear Explosions Treaties adequate to protect U.S. national security*. Since it has been convincingly demonstrated that these treaties are in our security interests, and since additional verification measures have not been well formulated, a requirement for on-site monitoring should not be raised as new condition for ratification. Rather, with further research and study, new monitoring techniques may prove appropriate for verification of a comprehensive test ban or drastically reduced threshold test ban.

With respect to verification, it is important to understand how much is necessary. That is, our challenge is to ensure verification adequate to protect our national security without demanding so much that we shoot ourselves in the foot. As the President himself has admitted, there will never be any such thing as "absolute" verification -- and there need not be. The intelligence process is often like a jigsaw puzzle. That is, the picture becomes clear long before the last piece is put in.

Certainly it can be said that any improvements in monitoring technology are useful. One can never object to better and more precise intelligence. At the same time, Mr. Chariman, I must issue a warning against sacrificing a possible agreement by insisting on gilding the lily of monitoring. The question again revolves around the security of the United States. Are we not better served by nailing down an essential limitation on Soviet testing, even if we set aside additional (and unproven) monitoring techniques which are beyond what is necessary to protect the security of the United States?

Many of our arms control initiatives have foundered on exactly this question. The most dramatic example was the negotiation in 1963 for a comprehensive test ban following the successful completion of the Limited Test Ban Treaty. As I have had the history recounted to me by some who participated in those negotiations, one of the issues that led to the failure of those negotiations was the American insistence on seven inspections a year and the Soviet unwillingness to accept more than three. Since that time we have learned that the Soviets may have been prepared to go up to four a year, and that some of our officials were prepared to go down to five. The difference between four and five inspections seems a minor matter when compared with the many developments in nuclear weaponry since 1963. If that treaty had been completed with a limit of either four or five inspections a year, and had been essentially complied with (and I believe that we could have monitored it adequately for that purpose), we might have halted certain weapons development by which the Soviets greatly increased their nuclear threat to the United States. It is obvious that our security has been reduced, rather than protected, by the failure to reach that agreement.

We face a similar problem today. These treaties, if ratified and complied with, will constrain the Soviets from certain further warhead developments. These include both higher-yield warheads and lighter, more efficient warheads that would enable the Soviets to take advantage of their greater throwweight and proliferate many more warheads on existing missiles. Beyond these treaties, a comprehensive test ban, or at least a drastically reduced threshold, could prevent the development of other nuclear weapons which threaten to expose our country to further risks. For example, the Administration has recently decided to pursue development of mobile missiles rather than depending exclusively on silo-based missiles for our land-based deterrent forces. The Soviets are already moving in a similar direction, altogether a positive contribution to strategic stability. But this could be negated by the development of nuclear weapons tailor-made to destroy mobile missiles. Already we are reportedly researching the possibilities of such "barrage" weapons as enhanced electromagnetic pulse or microwave weapons. Another so-called "third generation" nuclear weapon with potentially very destabilizing characteristics is the X-ray laser, part of the President's Strategic Defense Initiative. And if we are pursuing such weapons, we can be sure that the Soviets will eventually follow.

The Threshold Test Ban and Peaceful Nuclear Explosions Treaties make an important contribution to our national security in their own right by constraining development of Soviet nuclear weapons. Moreover, ratification of these treaties would give impetus to further negotiations, possibly leading to a comprehensive test ban or at least a much lower threshold of 10 to 15 kilotons or less. Ratification should also help the climate for substantial reductions in offensive weaponry. Since we have the capability to verify Soviet compliance with these treaties, they should be swiftly ratified without reservations.

Thank you Mr. Chairman.

Prepared Statement of Wolfgang K.H. Panofsky

I appreciate very much the opportunity to present my views on the ratification of the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET). I have had two previous opportunities to testify on the subject before this committee, once on September 12, 1974, and again on September 15, 1977. In those two previous statements I elaborated on the merits of these treaties in relation to non-proliferation of nuclear weapons, their effect on nuclear weapons technology, and on the role of the TTBT as a step towards attaining a Comprehensive Nuclear Test Ban Treaty. This is a goal to which the United States remains formally committed through the language of the Limited Test Ban Treaty of 1963 and the Nuclear Non-Proliferation Treaty of 1968.

I am the Director Emeritus of and Professor at the Stanford Linear Accelerator Center. I am also the Chairman of the Committee on International Security and Arms Control of the National Academy of Sciences of the U.S. I am, however, testifying here as a private citizen who has maintained contact with military and arms control problems since witnessing the first nuclear explosion at Alamagordo in 1945.

During my testimony of 1977 I emphasized that the threshold of 150KT is much higher than a value which could conceivably be justified as required to assure verification of the occurrence of such an explosion. This threshold was clearly chosen to make the treaty acceptable in view of the commitment for testing nuclear explosives which the parties wished to maintain. During the early hearings I endorsed ratification of the TTBT with the proviso that this ratification should in no way lessen the momentum towards reducing further the size and frequency and then eliminating entirely the detonation of nuclear explosives. I should also like to note that neither the TTBT nor the PNET identifies a valid method through which peaceful and military nuclear explosions can be distinguished. Rather, the PNET serves the purpose of assuring that the individual explosives used for peaceful purposes shall not have a yield larger than the limit provided by the TTBT. In the interest of economy of time I will not repeat the arguments supporting these earlier conclusions.

By virtue of the above history the threshold of 150 KT is somewhat arbitrary; it is indeed paradoxical that while in my view the 150KT threshold should primarily be a milestone on the way towards further reductions of nuclear testing, the precision to which this yield can be determined has now been introduced by the Administration to be a matter of major import.

Compliance with a threshold specified in a Threshold Test Ban Treaty can never be determined with absolute precision. There are two reasons for this fact: (1) the means of measurement available either by National Technical Means or by more intrusive measures are by their nature subject to uncertainty; (2) the weapons designer cannot predict precisely the yield with which the explosive will detonate. Therefore if a yield threshold, i.e. a threshold of energy release is established the designer would have to design for a lower yield; such a factor of safety would be required as insurance against an excursion to higher yield; even then there remains the possibility that with the best intent of not breaching the threshold, an occasional excessive yield might inadvertently arise. These uncertainties were recognized during the negotiating history of the TTBT and are incorporated in an exchange of letters between the parties which stipulate that "one or two slight unintended breaches per year would not be considered a violation of the treaty," but that such breaches would nevertheless be a cause for concern.

Although the treaty has not been ratified it has been a successful arms control measure within its admittedly limited scope. Before 1976 the Soviets detonated many large explosions in the multi-megaton region. Since March 1976 the Soviets have carried out about 190 underground nuclear tests. Of these only three or four have involved yields sufficiently near the threshold of 150KT to be a cause of concern, and there exists no persuave evidence either from seismological or from other sources which indicate that the Soviets have exceeded that threshold. Thus I find the assertion by the Administration that the Soviets have "probably violated" the 150KT limit to be unsupported by fact, and at any rate the overall compliance record of the Soviets and the United States with the unratified TTBT has been very satisfactory.

The issue before the Senate is now whether to recommend ratification of the treaty as signed by President Nixon in 1974 or, as proposed by the Administration, to recommend such ratification with reservations which would require the Administration to negotiate a Protocol strengthening the verification provisions of the treaty, or alternately, not to recommend ratification at all.

It is my view that as a matter of policy the treaty process requiring the Senate to recommend to the President ratification by a two-thirds majority should not introduce reservations or require the enactment of additional Protocols unless there are overriding reasons of national security to do so. In my view this is not even remotely the case in this instance in view of the following facts:

1. There is no persuasive evidence that the Soviets have violated the unratified treaty.
2. The military importance of the type of variations in yield which might be difficult to observe under the provisions of the TTBT as signed is minor.
3. The National Technical Means of verification could be improved significantly unilaterally by the United States. The more invasive verification methods, including the so-called Corrtex Method, which require a more intrusive on-site presence are subject to uncertainties of their own which could only be reduced by means which are likely to prove unacceptable to

the Soviet Union and also to the United States.

Let me elaborate on these conclusions. I already cited the compliance record with the unratified treaty as good. As far as the military importance of yield is concerned, it should be noted that by virtue of tests conducted by the parties prior to the 1976 date specified in the TTBT both the Soviet Union and the United States have in their stockpiles many types of weapons in excess of 150KT. The strategic importance of raw yield of a nuclear weapon is much less than that of other parameters of a strategic delivery system. For instance, if the yield of a weapon were increased by a factor of 2 its hard target kill potential would be enhanced by the same amount as if its accuracy were improved by only 26%! Similarly the lethal area of nuclear weapons in anti-population attacks increases only slowly with yield. Thus the military importance of small variations above the 150KT limit is minor.

Others are more qualified than I to testify about the precision of yield assessment which can be made by teleseismic means as provided now in the TTBT. A factor of 2 uncertainty in yield measurement is the conventionally quoted figure but it is clear that this number can be significantly improved with appropriate effort. A missing link is always the lack of detailed knowledge of the seismological characteristic of the test site. The TTBT as signed provided some requirements for [illegible] exchange of data on the subject, although the significance of such data exchange is limited.

Some attention has been focused on the so-called Corrtex Method which is a method of yield assessment requiring intimate access to the test location. Here a bore hole roughly 50 feet or so away from the location has to be drilled and a cable has to be inserted in such a hole. Note that U.S. domestic experience with this method with the exception of a very small number of shots is restricted to experiments in which this cable is inserted directly into the primary bore hole through which the explosive also has been inserted and which incorporates the test instrumentation devices.

The Corrtex Method does not measure yield directly but rather the speed of the expanding shock wave from the explosion which progressively shorts out the cable as the wave front progresses. Contrary to Administration assertion, the Corrtex Method is also sensitive to knowledge of the geological properties of the materials surrounding the shot, and it is also sensitive to many details such as the location of access shafts, etc. which characterize the test. Although again these uncertainties could be reduced by highly intrusive methods, some yield uncertainty would remain. The most accurate method of determining yield is radiochemical analysis; this would undoubtedly be considered to be too intrusive and too compromising to Restricted Data affecting nuclear device design to be acceptable to either party.

It should also be noted that the Corrtex Method becomes even more difficult to apply as the yield threshold is lowered; in contrast, refinements of teleseismic earth shock measurements such as those now in place in the U.S. seismic detection network would have important benefits in improving detection and identification of smaller yield shots.

For all the above reasons I strongly conclude that no valid case has been made why the TTBT as signed in 1974 should be modified, and I believe that an extremely bad precedent would be set if the Senate recommended such modification. Here we have a situation where a rather arbitrary milestone toward further limits in nuclear tests - 150KT in yield - is established in a signed treaty and now, to coin a phrase, the milestone is becoming a stumbling block if excessive and unjustifiable demands are made for the precision with which this yield is supposed to be determined.

Indeed, the verification of the TTBT has been introduced by the Administration as just such a stumbling block: whenever the Soviets have requested resumption of a meaningful dialogue leading to further reductions in yield and frequency of nuclear explosions, leading to their eventual elimination, the Administration has countered that the verification issue relating to the TTBT has priority. In my view there remain no valid compliance issues in regard to the TTBT as signed; this issue is an unjustified diversion of the process of negotiating more comprehensive measures.

This conclusion does not mean that efforts to improve means of verification should not continue; these should focus on improving detection and identification of nuclear explosives of lowest possible yield, not on measuring an arbitrary yield threshold with precision.

It would be an unfortunate precedent indeed if the Senate recommended ratification of the TTBT with reservations relating to verification, considering that there is no overriding national security interest in doing so. It would be a bad precedent in lengthening the already tedious arms control decision process further; this would further increase the risk that new technology will overtake the rate at which diplomatic progress can be made. If such a reservation were made, the Administration would have to negotiate more intrusive measures of verification with the Soviets which may well prove unacceptable. I note that the Administration statement which is incorporated in the official State Deparment paper on Limitation of Nuclear Testing, dated August 14, 1986, that "For their part the Soviets would be permitted to bring any equipment they deemed necessary to measure the yield of the test" would likely also be unacceptable to the United States.

Thus a reservation requiring additional verification measures beyond those incorporated in the TTBT as signed would be counterproductive. It would likely generate a new impasse in the drive toward further test limitations and it might even destroy the current regime in which the TTBT has been obeyed by both parties in the absence of formal ratification. Above all, it would be a most serious negative precedent for future arms control in that it requires modification of an already negotiated and signed treaty without a valid basis.

Let me therefore summarize my recommendation to this committee:

1. I recommend that the Senate transmit the TTBT as signed in 1974 to the President for ratification without reservation.
2. Should such an action not be acceptable I recommend that no ratification action regarding the TTBT be recommended.

September 7, 1977

STATEMENT BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE

SEPTEMBER 15, 1977

W. K. H. PANOFSKY

I appreciate very much the opportunity to present my views on Senate ratification of the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNE). I have had the previous opportunity to testify on the TTBT before this Committee on September 12, 1974, and I also testified on the desirability of a Comprehensive Nuclear Test Ban before a Subcommittee of this Committee on May 1, 1973. As before, I am testifying today as a private citizen who has maintained contact with the nuclear test ban problem since 1958.

It is characteristic of the problem before your Committee that remarkably little has changed during the period, commencing in 1958, in which this country has deliberated and negotiated on the question of cessation of nuclear tests. As you know, agreement was reached in 1963 on a Limited Nuclear Test Ban Treaty (LTBT) which banned nuclear explosions, military or peaceful, in the atmosphere, in space, or under water. This treaty has all but eliminated the adverse environmental consequences, primarily radioactive fall-out, of nuclear testing by its signatories. However, it has done little, if anything, to impede the development of nuclear weapons in the U.S. and the USSR, nor to affect stockpile confidence firings and most nuclear weapons effects tests. The LTBT has had the militarily significant result of preventing complete tests of single or multiple nuclear explosions as they affect the resistance of hardened missile silos to nuclear attack. Thus the LTBT has made it more difficult for a military planner to gain the information required to destroy ICBM's in their silos with very few survivors left to retaliate. In this sense, the LTBT has contributed to the maintenance of Minuteman as a viable arm of the U.S. deterrent forces for a long time ahead.

The LTBT has thus had a useful effect environmentally and, to a limited extent, has contributed to strategic stability. Yet most would agree that had we been able to reach agreement in 1963 on a Comprehensive Nuclear Test Ban (CTBT), adhered to by both the Soviet Union and the United States, and monitored by National Means utilizing the detection and identification capabilities which an improved seismology and other surveillance technologies can provide, then U.S. national security would have been stronger today.

As I have testified before this Committee on the earlier occasions cited, I believe that nuclear weapons technology is a mature art and that further nuclear weapons development may lead to some increases in efficiency or to adaptation to specialized missions, but is not apt to result in qualitatively new developments. Even numerical improvements in such quantities as yield-to-weight ratio are approaching a limit. I would like to add here parenthetcially that I consider the much discussed "neutron bomb" (the W-70-Mod. 3 warhead for the LANCE System) to be in the category of a specialized adaptation rather than a substantial departure from the role of other tactical nuclear warheads.

Since nuclear weapons technology is a mature undertaking, the detailed performance of most weapons systems, both in the strategic and tactical fields, is apt to depend more strongly on the evolution of the non-nuclear components of the system than on improved design of the nuclear warhead. Accordingly, any nuclear test restrictions at this time are not likely to have a significant impact on the arms competition between the U.S. and the Soviet Union. However, the principal motivation for pursuing a Comprehensive Nuclear Test Ban Treaty (CTBT) relates to the issue of nuclear non-proliferation. Here the linkage is both political and technical. By agreeing to the preamble of the Nuclear Proliferation Treaty (NPT), and as a signatory to the Limited Nuclear Test Ban, this country has undertaken a solemn obligation to strive in good faith toward the attainment of a Comprehensive Test Ban Treaty. The lack of progress on the part of the Soviet Union and the United States in reaching a CTBT has added to the cynicism with which the NPT is viewed by some nations and individuals. This cynicism would not be alleviated in itself, once this country has ratified the Threshold Test Ban Treaty now before the Senate. On the contrary, ratification of the TTBT would actually be counterproductive to the cause of non-proliferation if it served to diminish the pressure toward attainment of a comprehensive ban.

My recommendation, therefore, is that the Senate ratify the TTBT, but in a strongly expressed context that ratification is given with the full understanding that the TTBT is a step towards a comprehensive ban rather than a terminal objective in its own right.

The technical reason why a Comprehensive Test Ban Agreement would serve the cause of non-proliferation is, of course, the fact that a non-nuclear nation could not with confidence develop a nuclear explosive without nuclear testing. The LTBT of 1963 currently has more than 100 signatories, and it would be expected similarly that a comprehensive ban would be adhered to by a very large number of other nations. Accordingly, a CTBT would constitute a direct limit on the number of nations which could acquire nuclear explosives.

The previous remarks outline some of the main reasons for strongly supporting the thrust toward a CTBT. This Committee has, of course, heard and will continue to hear arguments expressing the opposite point of view. The arguments tend to fall into four categories:

1. The possibility that the Soviets would cheat under a CTBT and develop nuclear devices while the United States would not do so. As a result, the United States would suffer a serious military disadvantage.

2. The reliability of the U.S. nuclear weapons stockpile could not be verified under a CTBT.

3. The United States weapons laboratories would deteriorate under a CTBT while the Soviet laboratories could be maintained by coercion to function effectively.

4. A CTBT would interfere with programs currently planned for certain U.S. military systems.

Let me comment on each of these four arguments in turn.

1. Possible evasion. There is no question that, regardless of whatever progress is made in verification technology, it will always be possible for a determined evader to carry out a small number of tests at low yield that cannot be identified by national technical means alone. On-site inspection offers very little incremental verification capability. However, some residual risk of detection always remains even if technical verification means have not detected the violation.

It is exceedingly unlikely that results of such testing would be of substantial military significance. This conclusion is based upon the maturity of present nuclear weapons technology, and the fact that the performance of military systems is now largely controlled by the non-nuclear rather than nuclear hardware. As a result of this situation, the incentive to take the risk of evasion is very small, and the military consequences of evasion are minimal.

2. Stockpile verification. As far as the second argument is concerned, the Committee should note that it has been amply demonstrated that stockpile verification can be carried out without benefit of nuclear testing. On a longer time scale, there may well be a gradual deterioration on both sides in the confidence which military planners have in the reliability of the nuclear weapons stockpile. On balance, I believe this to be a beneficial effect in that it would tend to discourage preemptive counterforce strikes against the deterrent forces of the opponent. In contrast, the deterrent value of nuclear weapons is hardly affected by small decreases in reliability.

3. Weapons laboratories. A frequently heard argument against a CTBT relates to the viability of the weapons laboratories and the maintenance of a general research and development base for nuclear weapons. Indeed, in the absence of nuclear testing the viability of nuclear weapons development will be downgraded in time. I believe, however, that this applies both to the United States and the Soviet Union; a component of successful

arms control is that the military R&D capability of all parties be impacted. I do not believe in the assertion that the Soviet Union would be in a position under a CTBT to coerce highly productive weapons R&D while the United States would not. Creativity cannot be coerced. Wisely, the U.S. ERDA-supported weapons laboratories, namely Livermore and Los Alamos, have diversified their activity so that roughly half of their funding is now dedicated to direct energy-related programs. Some of the technology involved in such programs overlaps that of weapons technology; moreover, the United States has facilities superior to those of the Soviet Union in the field of computation related to weapons design and in simulation of weapons phenomena.

For these reasons, the assertion that a CTBT would impact the weapons R&D base of the United States more unfavorably that that of the Soviet Union is difficult to support. Moreover, should the treaty be abrogated, weapons competence could be restored to a present level permitting routine weapons verification tests to be resumed in a matter of a year or so, and full-scale development could be reestablished within several years. In addition, the abrogation of a treaty such as a CTBT would imply a major national emergency, and I should like to remind the Committee that in World War II nuclear weapons were developed starting from nothing but an idea in a period of only four years. If you combine these observations with the fact that the weapons stockpile based on existing designs will continue to be in existence, and also with the general maturity of nuclear weapons technology, I do not see how the matter of viability of the nuclear weapons laboratories can be a controlling factor or even a substantial consideration in judging the wisdom of proceeding with a CTBT.

4. Effect on present programs. The military impact of an arms control measure should be judged by a net assessment rather than simply by its effect upon planned U.S. weapons systems. A CTBT would naturally affect current U.S. plans, but this would also be true of Soviet activities. On balance, considering the state of technology, a CTBT adhered to by both

parties would lead to a small, but significant, gain in U.S. security, quite apart from its value in nuclear non-proliferation.

To summarize, for the reasons given above and those given in my previous testimony before this Committee, I strongly advocate a continuing major effort toward enactment of a CTBT, not as a significant tool in limiting the Soviet-U.S. arms race, but rather as a major step forward in limiting the proliferation of nuclear weapons.

Thus far I have been discussing the merits of a CTBT, rather than those of the TTBT and PNE treaties that are before your Committee. Let me turn now to the TTBT.

Were it not for the assumption that the TTBT should be viewed as a step towards a CTBT, and were it not also for the fact that the TTBT now before you has been negotiated in good faith by this government, I would be opposed to its ratification. Viewed as an agreement in isolation one might consider the TTBT to be "worse than nothing." The threshold of 150 KT is set so high that it bears little relation to the much lower threshold which might be related to confident verification by national devices observing seismic events. Therefore the conclusion that the magnitude of the threshold of 150 KT in the TTBT was defined by the desire of weapon designers to have the treaty offer a minimum impediment to their work is inescapable. Moreover, the very fact that the TTBT exempts peaceful nuclear explosions is a poor precedent for progress toward a CTBT. As has been amply discussed before this Committee, even with extensive, and probably unacceptably intrusive and expensive, inspection measures, there is no known way in which one can prevent military benefits from accruing from peaceful nuclear explosions. Therefore any exemption of peaceful nuclear explosions would negate a major non-proliferation objective of a test ban treaty. Once a non-nuclear nation has detonated a nuclear explosion, be it for peaceful or military purposes, it has joined the ranks of nuclear weapons states. Thus the distinction between military and peaceful nuclear explosions is fundamentally destructive to the non-proliferation objectives of any test ban treaty.

Notwithstanding this criticism of the TTBT if viewed in isolation, there is one constructive aspect of the inclusion of peaceful nuclear explosions in the TTBT and of the subsequent history leading to the treaty governing the conduct of PNE's. As the TTBT was framed in 1974, the design of detailed rules governing the conduct of PNE's was relegated to a separate negotiation. At that time it was not clear whether this separate negotiation would lead to the establishment of a different and possibly higher threshold for PNE's relative to the threshold of 150 KT specified for military explosions. After laboring for well over a year to arrive at a higher threshold for PNE's, the negotiators finally concluded that they were unable to do so in a manner which could be adequately verified. Therefore the PNE treaty and its annexed protocol now before the Senate constitutes an instrument which is designed to assure the nations of this world that the thresholds permitted for single peaceful nuclear explosions and for military explosions correspond to the same yield; *the treaty does not assure that peaceful nuclear explosions are in fact peaceful.* The negotiations preceding the treaty failed in arriving at mutually acceptable criteria which would distinguish military from peaceful nuclear explosions. This is an important lesson. It means that as we proceed to a Comprehensive Nuclear Test Ban Treaty peaceful nuclear explosions must be excluded entirely. There is no valid reason to extend hope that the negotiating effort which failed to achieve its goal of distinguishing peaceful from military explosions in the context of the TTBT will succeed in the context of a treaty in which military explosions are banned entirely. Therefore in moving towards a Comprehensive Nuclear Test Ban the nations of the world must realize that any conjectured benefits of peaceful nuclear explosions must be foregone.

As I have testified before, I do not believe that net benefits of peaceful nuclear explosions are significant, if they exist at all, and this point of view has now been generally accepted in the United States. Accordingly the "Plowshare" program formerly conducted vigorously by AEC/ERDA is now supported at a minimum level, and no U.S. nuclear test explosions for peaceful purposes are presently planned. This disillusionment stems from more realistic analyses relating to the economic aspects of nuclear explosions for peaceful purposes which have supplanted the more optimistic earlier assessments. Apparently the resultant pessimistic economic assessment is not fully shared by the Soviet Union. The Soviets are still continuing a PNE research and development program of moderate size and are reported to be insisting on an exception for PNE explosions in the negotiations now in progress which will hopefully lead to a Comprehensive Test Ban Treaty.

The interest in PNE's centers on excavation projects on the one hand, and a variety of underground engineering projects on the other; the USSR seems to be concerned with both. The Soviets have reaffirmed that they wish to adhere strictly to the terms of the Limited Nuclear Test Ban Treaty of 1963 (LTBT) which specifies among other provisions that underground nuclear explosions shall not lead to measurable radioactivity being propagated across the borders of the country conducting the detonation. Yet no one has demonstrated how excavation projects of any significance can be carried out which meet this criterion specified in the LTBT. Thus I do not believe that a PNE exception to a Comprehensive Nuclear Test Ban has any merit if its purpose is the conduct of excavation projects. Underground engineering projects, on the other hand, could be pursued in compliance with the LTBT. However, the economic incentives and even the feasibility for carrying out programs like gas and oil stimulation, reclamation of shale by *in situ* retorting, breeding of fissionable materials by thermonuclear explosions, and similar projects are very much in doubt. Moreover - and this to me is a controlling point - should the exploitation of PNE's for resource recovery projects such as oil and gas stimulation turn out to be economical, this would only be on a scale which requires nuclear explosions at a rate of hundreds or thousands per year. This in turn would demand an industrial technological base and traffic in nuclear explosives of a volume which involves dangers of diversion, highjacking, etc., that would dwarf the risks which are now under so much discussion in connection with the plutonium economy inherent to civilian nuclear power using reprocessing of fuel rods for the plutonium breeder reactor. Discussions of the possibility of verifying that peaceful nuclear explosions are indeed peaceful tend to ignore the enormous volume of explosions which has to be conducted, should PNE's really reach a state of productivity.

Let me relate these observations to my recommendation on the PNE treaty:

I recommend that the Senate ratify the treaty. In so doing the Senate should emphasize that this ratification in no way endorses a future PNE exemption or other special consideration for PNE's in connection with a CTBT. Rather, the Senate should emphasize that the very nature of the PNE treaty now being ratified is such that it does not distinguish between peaceful and military nuclear explosions. Instead, the treaty establishes criteria and procedures assuring that the yield of military and single peaceful nuclear explosions be essentially equal and thereby removes any incentive towards abuse of peaceful nuclear explosions for military purposes.

TESTIMONY BEFORE THE COMMITTEE ON FOREIGN RELATIONS OF THE U. S. SENATE

WOLFGANG K. H. PANOFSKY

September 12, 1974

In response to your invitation I am very pleased to accept this opportunity to testify on the relation of the agreements signed in Moscow, July 3, 1974, to the detente between the United States and the Communist countries, and to comment further on prospects for arms control. I am testifying as an individual citizen who has a long-standing interest in the control of arms to increase the real security of this country and the world.

Detente means relaxation of tensions - not necessarily accommodation of conflicting interests or of diverging ideologies. There is, however, a growing conviction that limitation and reversal of the nuclear arms race between the Soviet Union and the United States are becoming of overriding security interest to both sides. Naturally one hopes that effective arms control agreements will in themselves reduce tensions and remove barriers of communication, but such a conclusion is not automatic - in fact, arms control proposals can be and have at times been abused for furthering national political goals, and arms control agreements, if ineptly drawn, can heighten, rather than lower, distrust.

In this testimony I will concentrate on an assessment of the two 1974 Moscow agreements on Arms Control in view of the urgent threat of further proliferation of nuclear weapons and the growing strategic nuclear arsenals; I will conclude with remarks on the prospects and problems of Arms Control in an era of detente but continuing competition and ideological conflict.

A. THE PROTOCOL OF JULY 3, 1974, TO THE TREATY ON THE LIMITATION OF ANTIBALLISTIC MISSILE SYSTEMS

This Protocol to the earlier ABM Treaty of 1972 is the only substantive agreement in the strategic area emerging from the Moscow talks; there was failure in making the promised progress in controlling offensive strategic nuclear armaments. Nonetheless it is a positive contribution in that it restricts further any antiballistic missile systems to what from a military-strategic point of view is negligible effectiveness for both sides. Let me make some comments on some of the more detailed features of the Protocol.

1.) The 1972 ABM Treaty was an important step in Arms Control. By limiting deployment of ABM systems to what are in essence insignificant levels for strategic purposes, it implements its basic policy declaration: "Each party undertakes not to deploy ABM systems for defense of the territory of its country . . ." in the face of criticism that it enshrines the mutual hostage condition of the population of each country. However, as has been amply documented, this condition of mutual vulnerability of the population of both countries is the result of the massive nuclear weaponry deployed by both the Soviet Union and the United States and of the inefficiency of defenses against such a threat; mere changes of national policy or announced strategy cannot remove this mutual hostage relationship. Thus the 1972 Treaty has stabilized the states of mutual deterrence between the two countries.

2.) The 1972 ABM Treaty deserved criticism in detail in that it was in effect "arms control upwards" - both sides kept what they had but in addition were permitted to add what the other side had built or had under construction. This means that the negotiations preceding the 1972 Treaty were unable to resolve the conflict resulting from the fundamentally different ABM systems to which the two countries were then committed: The Soviets at that time had the 64-Interceptor

Moscow ABM Defense in being, while the U.S. had initiated construction of the Safeguard system designed to defend the missile silos in Grand Forks, North Dakota.

Although the levels of ABM's to which the 1972 Treaty restricts any future deployments are negligible from a military (but not budgetary!) point of view, the precedent set by the principle "each side may buy what the other side has" is highly undesirable. However neither party has in fact exercised its right to buy an additional ABM site: The Soviets have not demonstrated an intent to construct a missile defense around a strategic missile site east of the Urals, and as a result of Congressional action, the United States is not proceeding with constructing an ABM defense around Washington.

The 1974 Protocol now recognizes the existing asymmetry between the parties by restricting each side to the two ABM sites actually constructed; formally symmetry is preserved by permitting each side to destroy its existing ABM site and convert it to the type of deployment as existing on the other side. Needless to say, there is little expectation that such a move will be made.

One might criticize the Protocol of 1974 as simply legitimizing the *status quo* by prohibiting what neither side wished to buy at any rate. This comment is indeed valid, but the Protocol effectively reaffirms and strengthens the basic policy implication of the 1972 ABM Treaty.

3.) The absence of an effective ABM as assured by the 1972 Treaty and the 1974 supplemental protocol enhances the deterrent value of each reentry vehicle carried by U.S. missiles, since potential attrition through expanded ABM defenses is no longer of concern. Thus these ABM treaties should have (but have not!) reduced pressures for increased offensive strategic weapons by the two sides.

4.) The ABM Treaty as supplemented by the 1974 Protocol enhances the independent deterrence of our allies and also of China. Since ABM has been limited to a negligible level and localized in coverage, any small missile force deployed is assured penetration.

5.) Without commenting here on the value of a "flexible response" strategy, I note that the 1972 ABM Treaty and the 1974 Protocol enhance implementation of such a policy in that the U.S. missile forces can be programmed to any target of choice without substantial concern for unanticipated attrition through Soviet ABM defenses.

It is well to emphasize this point since in support of a flexible strategy in response to limited nuclear attacks new weapons developments are contained in current U.S. programs. The SALT I ABM Treaty which has been heavily criticized by advocates of a more flexible strategic policy for the U.S. is actually a large factor in permitting greater flexibility of targeting using existing weapons systems.

In summary, I consider the ABM Protocol of 1974 a useful addition to the 1972 Treaty which merits support and ratification by the Senate. The question, of course, remains why it was not possible, despite previously announced commitments by leaders of both countries, to attain an agreement on offensive nuclear weapons to supplement or replace the Interim Agreement of 1972. Many reasons account for this failure reflecting the politically unfavorable circumstances attending the Moscow negotiations. There was a preoccupation with reaching numerical agreement on MIRV numbers by the U.S. side, and concern with the question of forward-based aircraft by the USSR. There was a clear absence of self-restraint on strategic nuclear developments - including many which are clearly unproductive and costly on both sides. This failure means that offensive nuclear arms have continued to grow in numbers and complexity; the further this evolution proceeds the more difficult it will be to negotiate verifiable arms control agreements which ban or limit specific technical strategic offensive systems.

B. THE THRESHOLD TEST BAN TREATY (TTBT) OF JULY 3, 1974

In contrast to the ABM Protocol which, although a relatively minor addition to arms control, is a positive achievement, the TTBT raises a serious question whether it is a treaty "worse than nothing."

1.) The Merit of Nuclear Test Restrictions

I have had the privilege of testifying before the Subcommittee on Arms Control, International Law and Organization of this Committee on May 1, 1973, to give my views on the problem of transition from the Limited Nuclear Test Ban Treaty (LTBT) to a more comprehensive agreement. I will only summarize briefly my views given at that time.

My general conclusion is that, as far as the bilateral US-USSR military posture is concerned, and on a purely technical basis there are no arguments of great strength either for or against strengthening the Limited Test Ban Treaty into a Comprehensive Test Ban Treaty (CTBT), and certainly not for or against a TTBT. The primary reason for this conclusion is that the technology of nuclear weapons is reaching maturity and therefore the performance of military systems, in particular in the strategic area, is insensitive to nuclear weapons improvements. In the future the effectiveness of tactical and strategic weapons systems will be much more dependent on such non-nuclear developments as advances in accuracy, command and control, reliability, safety, etc. than they are on nuclear weapons advances *per se*. For this reason one cannot make a strong case technically against a CTBT in that such a treaty would constitute a large military risk, but conversely, one can also not make a strong argument that a CTBT would be a substantial factor in the control of the arms race.

While there are no overriding technical arguments either in support of a CTBT or in opposition to such a move, there are strong reasons why the thrust towards nuclear test ban agreements are more powerful than the LTBT must be maintained. These reasons stem from the imminent threat of the proliferation of nuclear weapons. A comprehensive nuclear test ban adhered to by the present co-signatories of the LTBT and hopefully by additional states would be a powerful tool in limiting the spread of nuclear arms. Moreover, the United States and the Soviet Union took the solemn obligation, both in the Preamble of the Partial Nuclear Test Ban Treaty of 1963 and in the Nuclear Non-Proliferation Treaty signed in 1968 and ratified by the Senate in 1970, to pursue in good faith steps aimed at the total abolition of nuclear testing. In this respect the TTBT of 1974 demonstrates to the non-nuclear nations a lack of progress by the U.S. and the USSR, if not outright cynicism; therefore efforts to curtail the proliferation of nuclear weapons has suffered a serious setback through the signature of this treaty.

2.) The Provisions of the Threshold Test Ban Treaty of 1974 (TTBT)

The TTBT of 1974 contains the following provisions: (1) nuclear weapons tests carried out by the signatories above an explosive power of 150 KT shall cease after March 31, 1976; (2) nuclear weapons testing by the signatory nations shall be held to a minimum as soon as the treaty comes into effect; (3) the provisions of the treaty do not apply to peaceful uses of nuclear explosions (PNE's) and a separate agreement is to be negotiated to cover such explosions.

This treaty is bilateral between the U.S. and the USSR. In contrast, the 1963 Limited Test Ban Treaty was a trilateral agreement (the U.K. was included). In the interest of limiting nuclear proliferation a total of 90 nations signed and ratified the Treaty. It is clearly not advisable to open the 1974 Moscow TTBT for signature of other nations: Its provisions are such that rather than constituting a limitation they would be widely interpreted as a license to test weapons of yield below 150 KT!

I note a frequent misquotation of the provisions of the Treaty in regard to the date of effectiveness: The Treaty enters into force once ratified by the appropriate bodies of the two nations. The date of March 31, 1976, applies specifically to the imposition of the threshold, while in contrast the provision restricting nuclear testing to a minimum would be effective on ratification. It has been customary in the past for nations who have negotiated a treaty on the Executive level to live up to its terms whenever possible without awaiting ratification; therefore, acceleration of nuclear testing by either party, or even continuation of nuclear testing at the current rate would be in contradiction to that tradition.

3.) The TTBT and Verification

In the past it has been declared policy of the United States in consonance with the obligations taken under the Limited Nuclear Test Ban Treaty and the Non-Proliferation Treaty to support a Comprehensive Nuclear Test Ban, provided it can be "adequately verified." It is, however, impossible on technical grounds to reconcile the Moscow Treaty of 1974 with that official position: The threshold chosen (150 KT combined with restriction of testing to a site of announced geophysical characteristics) is incompatible with testimony from all sides that the existing U.S. seismic network can distinguish earthquakes from explosions by seismological national means alone at a much lower explosive yield. Moreover, improvements to the existing seismic network can be made, provided appropriations for that purpose are available and national means of verification other than those using seismology reduce greatly the number of seismic events which could not be sorted into either explosions or earthquakes. Most important is the fact that the gap between detection and identification has been substantially narrowed in recent years. In consequence "on-site inspection" on which the U.S. has insisted in the past as a condition for agreement to a treaty banning all nuclear tests adds little, if anything, to the certainty of identification of a clandestine nuclear test beyond that attainable by national means.

There is now general agreement among all parties in the United States that the number of seismic events in the Soviet Union unidentified by the present network above seismic magnitude of, say, 4.5 has become a very small number indeed. In contrast, a 150 KT shot fired at the Soviet Semipalatinsk nuclear test site is expected to produce a seismic signal of about 5.75 magnitude, while a shot at that site giving a magnitude of 4.50 corresponds to only about 10 KT. Thus there is no scientifically valid excuse to justify a threshold as high as 150 KT as being required for verification; therefore the high value of this threshold is in contradiction to previously announced policy and therefore can be interpreted as being in violation of the obligations taken under the preambles of the Limited Nuclear Test Ban Treaty and the Nuclear Non-Proliferation Treaty.

When a threshold treaty was under discussion in the past it has been customary to specify the value of the threshold in terms of the seismic magnitude of the earth motion produced rather than by the yield of the explosion which causes the disturbance. The reason for this earlier custom is that the limits of distinguishability between earthquakes and man-made explosions relate to observed seismic magnitude rather than to the size of initiating event - the reason is that the "coupling medium" in which the event takes place can make a substantial difference to the relationship between seismic magnitude observed and the energy release in the initiating seismic event. In the Protocol annexed to the 1974 Moscow Treaty there is a requirement for the Soviets to furnish data to calibrate the U.S. seismic network so that the relationship between the size of nuclear explosion at the Soviet test site and the seismic signal received by the U. S. detection network can be established. This requirement appears to be patently absurd: The purpose of all seismic detection procedures is to prevent Soviet cheating; yet in the Moscow Treaty we are relying on the Soviets to calibrate our

our instruments by declaring (without verification!) the magnitude of the calibration event - clearly it is technically feasible for the Soviets to detonate a device of yield considerably larger than that declared; this would make it possible to operate *de facto* at a higher threshold in the future.

I am by no means trying to imply in this testimony that there is a large liklihood that the Soviets will adopt elaborate cheating or evasive measures in relation to this treaty; considering the magnitude of the threshold chosen they would have little incentive to do so at any rate. However I would like to point out the patent inconsistency between U.S. early insistence to oppose a comprehensive nuclear test ban or a test ban with a low threshold by invoking the spectre of very elaborate evasion schemes while now agreeing to methods of verification with flawed internal logic.

I thus conclude that the large magnitude of the threshold, the curious seismic calibration requirement, and the late date of implementation (March 31, 1976) of the threshold limitation cannot be related on technical grounds to the requirement of "adequate verification" stated as being U.S. national policy. There is, therefore, no escape to the conclusion that the Moscow Treaty of 1974 is specifically designed to accommodate those on both sides who wish to continue nuclear testing with minimum impairment.

4.) The TTBT and Weapons Development

The Moscow Treaty offers only a minimum impediment to the evolution of nuclear weapons. Some have maintained that since the Soviets have larger weight-carrying capacity on their missiles than does the U.S., the explosive yields of their warheads, even if subdivided into MIRV's, would be larger than 150 KT, and that therefore Soviet MIRV development might be impaired by the 1974 TTBT. Granting this assertion, it is likely that the Soviets will have tested before March 31, 1976, their first and possibly second generation MIRV'd warheads as required for their ICBM's now under test in the current series, and it is also likely that MIRV'd submarine missiles will carry warheads of yield below 150 KT. On the U.S. side the limitation is even less significant since few warheads planned for U.S. strategic missiles will exceed the threshold, and that those which are planned to do so can presumably be tested before the date the threshold is imposed.

Thus, without dealing with the detailed military significance of the TTBT of 1974, the above examples illustrate that the threshold of 150 KT is so high that the military effect is negligible - a consequence of the fact that this threshold is still one order of magnitude - about a factor of 10 - larger than the explosive power of the bombs which devastated Hiroshima and Nagasaki.

5.) The TTBT and Peaceful Nuclear Explosions (PNE's)

Probably the greatest defect of the Moscow TTBT is the way in which it deals with the problem of PNE's.

a) Treaty Provisions with PNE's - Such explosions are exempted from control under the treaty entirely as now written but a commitment is made that a separate protocol will be negotiated "at the earliest possible time" to deal with this subject. In principle the Administration could submit the 1974 TTBT treaty for Senate ratification prior to negotiation of this separate agreement, but I see no evidence that the Administration intends to do so. Therefore, until such a separate agreement has been negotiated, the TTBT of 1974 is to all intents and purposes non-existent; for reasons to be given below, I doubt that such an agreement which is technically consistent with reasonable verification requirements, can in fact be designed.

b) The Economic Viability of PNE's - Within the United States the enthusiasm (and budgets!) for peaceful nuclear explosions has drastically declined in recent years as the economic and environmental deficiencies of PNE's have become more widely recognized. Interest in excavation projects has essentially disappeared, and projects such as underground heat deposition, gas recovery, shale extraction, and construction of underground gas storage vaults require explosives of yield generally less than 150 KT; recent experiments on such projects have been largely unsuccessful. Therefore PNE's for other than excavation projects, whatever their economic merits might be, would not require a PNE exception to the Moscow Treaty as currently written.

Most important is the fact that if peaceful use of nuclear explosions has any merit at all, then the total number of shots per year required to have any significant economic impact on the world's energy resources or on other economic needs would be wildly excessive and clearly unacceptable. For instance, even if it were possible to recover the thermal energy released by detonating nuclear devices underground in order to add to the nation's electric energy supply, one would roughly require one hundred thousand 100 kiloton explosions per year in order to increase the nation's present energy output by 10%! Approximately 1,000 explosions would be required to increase the nation's natural gas supply by 5%. The Kama-Pechora Canal, which is believed to be the primary Soviet motive for wishing to include a PNE exception in a Threshold Test Ban Treaty, would require detonation of several hundred devices above the 150 KT threshold; the reports on that canal which we now receive from the Soviet Union are very similar in flavor to those prevalent in the United States concerning the construction of a second Trans-Isthmian (Panama) Canal by nuclear means before the final report of the Trans-Isthmian

Commission was issued. Prior to that report savings of several billion dollars were projected by the proponents of nuclear excavation methods. Once the report was rendered it became clear that the savings were illusory once the economic impact of all considerations was taken into account.

c) Verification of PNE's as Peaceful - It has been well established for a long time that distinguishing peaceful from nuclear explosions is technically difficult, if not impossible, and that under the very best circumstances such distinction would require inspection measures which are so intrusive as to be unacceptable to the Soviets. Clearly a general provision permitting a limited number of inspectors to be present near each detonation site is insufficient to assure verification of peaceful purposes. What, then, are the possible approaches?

One frequently proposed method for verifying PNE's as peaceful is to require that a PNE should conform to predeclared technical characteristics; in other words, a peaceful explosion should be based on a device withdrawn from existing stockpiles. Such a general provision is intended to prevent new weapons developments under the guise of peaceful detonation, but would still permit a military loophole by allowing proof testing of existing military stockpiles and it would also permit limited military "effects" tests by exposing devices of military interest to the radiations from the "peaceful" explosion. Such a provision would prevent development tests of nuclear devices specifically for PNE purposes; since the economic utility of PNE's is already at best marginal, nuclear device developments specifically for PNE purposes might well be required; therefore control provisions based on existing stockpiles might be unworkable in practice. Finally, even if there were a requirement that "peaceful nuclear explosions" should conform to preannounced characteristics one would face the problem of failures: How does one distinguish failure of a stockpile device from a weapons development test yielding technical indications differing from those declared?

Another suggestion for distinguishing PNE's as "peaceful" is to require the explosive to be "unsuitable for military use." For reasons I cannot discuss here I doubt the feasibility whether one can indeed make a nuclear explosive sufficiently "awkward" to prevent military application; however, at any rate verification that a PNE really meets such awkwardness specifications means that the products of the explosion would have to be analyzable by U.S. or international inspection teams. This means that either there has to be access by such inspectors to the underground explosion products through backdrilling (or relying on samples furnished by the country carrying out the explosion!), or the explosion would have to vent so that gaseous radioactive products of sufficient quality to permit analysis became available.

d) PNE's and the 1963 Limited Test Ban Treaty - The question of venting raises another problem of paramount importance: That is the relationship of the Moscow 1974 TTBT to the viability of the 1963 Limited Nuclear Test Ban Treaty. In the past several U.S. underground nuclear test shots and a large number of Soviet shots have "vented," and several events have released radioactivity measurable outside the boundaries of the country carrying out the explosion, in formal violation of the 1963 Limited Nuclear Test Ban Treaty. In the past neither side has chosen to challenge such transgressions as intentional; indeed many, if not all, occasions of venting could well be due to miscalculations on the required safety factors in determining geological siting of the events or the depth of burial. However there is no question that economically viable excavation projects could not be carried out except by deliberate violation of the terms of the Limited Nuclear Test Ban Treaty; if in addition verification methods would involve radioactive sampling of events *required to vent*, then the 1963 Limited Nuclear Test Ban is indeed in trouble. In short, interpreted along these lines, the 1974 Treaty represents a step backwards in arms control.

e) *PNE's and Nuclear Weapons Development* - It is very difficult indeed to distinguish between sincere, but possibly misguided, advocacy of PNE's and cynical promotions of PNE's to further advances in nuclear weapons technology.

The preceding remarks have documented briefly the technical near-impossibility of verifying that a peaceful nuclear explosive is indeed peaceful. In the past opponents of more far-reaching nuclear weapons test restrictions (including a comprehensive nuclear test ban) have demanded very high standards of verification to prevent Soviet cheating by invoking such elaborate evasion techniques as the "big hole" and nuclear testing under cover of natural earthquakes or behind the sun or moon; yet provisions exempting peaceful nuclear explosions of yield above the threshold which could lead to very much easier opportunities for evasion are apparently acceptable!

I believe a substantial disservice to the future expectation of mankind to prevent non-proliferation of nuclear weapons has been done by attempting to provide for a separate PNE agreement in the TTBT and thereby endorsing the exaggerated significance which some nations appear to be giving to the economic and prestige importance of peaceful nuclear explosions. Defenders of the recent Indian nuclear explosions have already invoked the PNE provision of the Moscow TTBT to bolster the claim of peaceful intent; yet few would doubt that this test is a dangerous break in the barrier provided by the Non-Proliferation Treaty in stemming the spread of nuclear weapons. Many will recall that when in 1949 Mr. Molotov announced to the United Nations the first detonation of a Soviet nuclear device he stated that the Soviet's purpose in developing nuclear explosives was "to move mountains and to dam rivers."

6.) Recommendations Concerning the 1974 TTBT

Based on the foregoing I recommend strongly that efforts to negotiate a separate agreement permitting peaceful nuclear explosions above the threshold be abandoned and that the provisions of the Moscow 1974 TTBT exempting peaceful nuclear explosions from the other provisions of the treaty be deleted. Moreover, in consonance with the obligations taken under the Limited Nuclear Test Ban Treaty, the Nuclear Non-Proliferation Treaty, and reemphasized in the 1974 Threshold Test Ban Treaty itself, I recommend strongly that efforts to negotiate a treaty prohibiting all nuclear tests after a fixed date without an exemption for peaceful nuclear explosions be resumed vigorously.

D. CONCLUDING REMARKS - DETENTE AND ARMS CONTROL

1.) Future Directions for SALT

The foregoing testimony paints a rather depressing picture of the progress in arms control made during the period since 1972 in the face of improved detente between the U.S. and Communist countries. Clearly the pace of military technology pursued by both parties has not slackened and may in fact have increased. Nuclear arms are growing in numbers and complexity and therefore the chance of negotiating future arms control agreements which will be considered verifiable within conservative standards and which prohibit or limit specific military systems are being lessened. The progressive failure of arms control measures to keep pace with military-technological progress is thus narrowing the opportunities for effective arms control - the principal remaining hope is a goal of broad agreements on *limiting and hopefully reducing over-all aggregates of selected classes of strategic weapons and on general technology restraints such as lowered limits on the permitted rate of missile firings.* I recommend strongly that such agreements be pursued at SALT.

The Soviet Union and the United States enter into arms control discussions with profound asymmetry: political, economic, geographic and strategic. Therefore interpretations of a guiding principle such as "essential equivalence" of strategic forces or strategic "parity" will naturally differ greatly if the realities are interpreted through the perceptions of the two sides. Consequently the debate as to "who is ahead" in nuclear strategic armaments using detailed numerical indices of strategic power such as numbers of launchers, numbers of warheads or throwweight deliverable by missiles is bound to be contentious and counterproductive.

2.) Increased Armament in the Name of Arms Control

Probably the most destructive tendency during the past years has been the use of arms control negotiations or agreements as tools toward actually accelerating military development and even deployment. This trend has been expressed in this country through the "bargaining chip" philosophy expressed by the Administration through support of proposed military systems or developments as being needed to provide leverage at the bargaining table with the Soviets. Thus in the face of convincing technical criticism that the Safeguard ABM system was a very poor use of the defense dollar, Congressional approval was attained by invoking the need for strengthening the hand of U.S. negotiators. I note that even after SALT I the Administration proceeded to request deployment of the second ABM site permitted at that time; had the Congress granted that request it would have been almost certainly impossible to make the further reduction negotiated in the ABM Protocol of 1974.

History is making it abundantly clear that the bargaining chip technique is escalatory and ineffective in negotiating with the Soviets. The primary reason why it has been impossible to arrive at an accommodation with the Soviets in the control of MIRV is that the Soviets do not wish to be frozen in a position of inferior technology. Therefore the unrelenting advance carried on by the United States in MIRV deployment and in research and development programs generating more accurate MIRV warheads carrying higher explosive power has now been demonstrated to be an impediment toward reaching a satisfactory agreement with the Soviets rather than as an effective "bargaining chip" which exerts constructive leverage at the table. The history of the arms control negotiating relationship between the United States and its Communist adversaries has been replete with such incidents: As long as U.S. military technology in a given area is vastly superior to that of the opponents, a negotiated agreement cannot be reached - this was the case during the early period of extreme nuclear superiority by the United States and it is now the case in relation to China: At this time the Chinese tend to view arms control negotiations as a means of freezing the lesser developed parts of the world in a position of inferior technology.

The accelerating effect of arms control negotiations on domestic military programs has been demonstrated repeatedly; after signature of the 1963 Limited Nuclear Test Ban Treaty President Kennedy agreed under pressure that the price for Senate ratification of the treaty would be implementation of four so-called safeguards, one of which required underground nuclear testing at a pace "comprehensive, aggressive and continuing." As a result underground nuclear testing by the United States has exceeded that of the Soviet Union by a substantial factor. More recently SALT I ratification was followed by the initiation of a substantial number of new research and development programs justified by the "bargaining chip" philosophy and currently the Congress is again being faced with a large supplementary budget request to accelerate nuclear testing before the 150 KT threshold is imposed - this despite the fact that the 1974 treaty has not as yet been submitted to the Senate for ratification, and in spite of the fact that the negotiations of the separate agreement to control peaceful nuclear explosions have not as yet commenced.

I would like to recommend strongly that the standard under which requests for military authorizations and appropriations are scrutinized by the Congress should not be lowered in order to apply a conjectured but ill-documented leverage at the bargaining table, or in order to seek quick military gains before an impending treaty deadline. We are facing an evil dilemma: On the one hand comprehensive arms control agreements are extremely difficult to attain under current circumstances. On the other hand partial arms control agreements immediately give rise to pressures by the military establishments of both sides to compensate for those partial limitations in areas not as yet controlled. The only hope towards slowing or reversing the destructive competition in nuclear weapons between the East and West at this time would be effective internal resistance to such pressures leading to restraint on both sides.

3.) Nuclear Weapons and Political Goals

Let me conclude with a plea aimed at both the Executive and Legislative Branches for a deliberate de-emphasis of the value of nuclear weapons as a means of achieving political goals and of furthering national prestige. No strategic writer or proponent of new nuclear weapons systems has made a plausible case, let alone a convincing one, in projecting an occasion in which nuclear weapons can be rationally used in a war of the future. It is this situation which is the background of Secretary Kissinger's agonized remark made in his Press Conference of July 3, 1974 " . . .and one of the questions which we have to ask ourselves as a country is what in the name of God is strategic superiority? What is the significance of it politically, militarily, operationally, at these levels or numbers? What do you do with it?" Yet in the face of evidence that nuclear weapons are not usable without risking an escalation to an all-out conflict which would cause mass destruction totally disproportionate to the goals at hand, military spokesmen on both sides continue to support further acquisition of military nuclear strategic hardware as required tools of international diplomacy; they invoke the spectre of "nuclear blackmail" lending pressure to otherwise unacceptable demands. There is no reasonably persuasive evidence that such nuclear blackmail has been or would actually be effective; yet the very fact that the potential of nuclear blackmail continues to be invoked by the large nations lends prestige value - even if not demonstrable political, let alone military value - to the acquisition of nuclear weapons. It is this pressure combined with the technically totally misguided emphasis on the peaceful uses of nuclear explosions which makes resistance to proliferation of nuclear weapons to the present non-nuclear nations so difficult.

The problem of proliferation of nuclear weapons is becoming possibly the greatest nightmare facing the world today. A treaty as defective as the TTBT now negotiated signals to the world a lack of concern by the U.S. with the proliferation issue. This matter, together with the recent "peaceful" Indian test and our willingness to distribute nuclear reactors as symbols of American aid in troubled areas of the world, might well create a climate leading to rapid expansion of nuclear weapons developments all over the world. Moreover, recently the pace of technological military progress has exceeded the pace of successful arms control. Only restraint by all parties on the broad front of nuclear armament combined with bold steps in negotiated arms control can reverse this potentially disastrous course.

Prepared Statement of Milo D. Nordyke

I would like to thank you, Mr. Chairman, for the opportunity to address this committee on the issue of the TTBT and PNET and their verification. At the outset, I should like to make it clear that I am speaking as an individual who has wrestled with the problems of negotiating and verifying treaties such as the TTBT and PNET, and not as an official representative of the Lawrence Livermore Laboratory. I will briefly summarize my views on the problems inherent in verifying treaties such as the TTBT and PNET which contain quantitative limits as well as make a few comments on ways in which the verification regime for the TTBT can be enhanced.

TTBT Verification and Compliance Issues

Verification of any treaty, such as the TTBT, which involves the measurement or counting of some observable such as yield, requires that you deal with uncertainty - something that is very difficult to handle at the political level. This is true, regardless of how accurate or precise the measurement system is. Moreover, the problem is compounded by the fact that there are two types of errors involved - what scientists call "random" errors and "systematic" errors. I sometimes try to relate this problem to one of using a home scale to monitor whether you are sticking on a diet. The scale reading may vary from day to day because of what you are wearing or how long its been since you ate or because the scale sticks or other random factors, but on the average, it will give you the correct value. Unless - someone has fiddled with the "zero adjust" knob, in which case, if they turned it up a little bit, every time you weigh yourself you will systematically, always be over your diet. Verifying compliance with the TTBT suffers from the same two types of errors - random and systematic.

Estimation of the yield of a Soviet nuclear test is based on measurements of its seismic magnitude as determined by a high-quality, world-wide network. Then, this magnitude is used with a yield-magnitude relationship based on experience with explosions for which we know both the yield and the seismic magnitude, to estimate a yield for the Soviet explosion. Evaluation of compliance with the TTBT yield limit will then depend on the two sources of error discussed above: 1) is the yield-magnitude relationship we are using correct for Soviet tests or is there a systematic difference between our test site and the Soviet test sites? and 2) how should we deal with the random errors that are inherent in the seismic magnitude determination, seismic coupling, propagation and receiving processes?

With regard to the first issue - the possibility of a systematic error - the key question is whether the magnitude-yield relationship developed for explosions at the Nevada Test Site is valid for explosions at the Soviet test sites. Seismic research at LLNL and elsewhere as early as 1973, well before there was any thought being given in the arms control community to the subject of a yield-based threshold treaty, indicated the existence of a significant difference in the character and amplitudes of the seismic waves from the Soviet nuclear explosions. I don't think this surprised any seismologists or geophysicists because there are very well-known, obvious differences in the tectonic structure of the earth between these two areas of the world.

Over the last 10 years close to 20 different seismic studies utilizing different techniques and different seismic waves have been carried out by various investigators to try to quantitatively understand this question. Virtually all these studies have shown that the seismic magnitude from an explosion of a given yield at the Soviet test sites will be larger than the seismic magnitude from an explosion of the same yield at NTS. This offset or difference has come to be known as the "bias". The estimates of the bias vary somewhat from one study to another but, on the average, they have values that leads to yield estimates for Soviet explosions that are about 40-50% of the yields obtained from the NTS magnitude-yield relationship. Because the effect of the bias correction is to shift almost the entire body of Soviet yield esimates to lower values, the value of the bias used for yield estimation has a major impact on one's view of the question of Soviet compliance with the yield threshold.

With regard to the second issue, random variations in the seismic data can make the estimated yield of any explosion appear to be either smaller or larger than its actual yield, even if the bias is known. For example, if we were to carry out a series of explosions with actual yields of 150 kt, on the average half of them will have estimated yields greater than 150 kt, and half smaller, regardless of how accurate the measurement system is. Thus, the occurrence of a yield estimate above 150 kt does not necessarily imply a violation. The existence of random errors in your measurement system means that issue of compliance must be dealt with in a statistical framework.

LLNL was one of the first to carry out statistical studies of the question of Soviet compliance with the TTBT, based on the pattern of Soviet test magnitudes and on the best estimates of the magnitude bias.

Based on these assessments of the best relationship between yields and seismic magnitudes for the Soviet test sites and the patterns of Soviet testing, it was concluded that the Soviets appear to be observing a yield limit. The best estimate of this yield limit is that it is consistent with TTBT compliance. However, because of the statistical uncertainty of yield estimates and the uncertainty in extrapolating U. S. experience to Soviet test sites, you cannot rule out the possibility that a few Soviet tests may have exceeded the limit.

It should be obvious from all the technical factors discussed above, that it is impossible to state with 100% certainty that the Soviets have or have not violated the TTBT. Because of the statistical nature of the available data, we are forced to deal with probabilities and consistencies. The critical issue is whether the yields of the possible Soviet violations will give the Soviet Union a militarily significant advantage. I would not be qualified to discuss the military significance of the alleged violations but based on mv personal assessment of opinions in the nuclear weapons community, it does not appear to me that the yield range of possible Soviet violations would open up unique nuclear design opportunities.

Suggested Improvements in the TTBT Verification Regime

Since April 1, 1976, the U.S. and the USSR have agreed to observe the 150 kt limitation provided for in the Threshold Test Ban Treaty, pending ratification of that Treaty. However, since the treaty has not been ratified, the two parties have not carried out the exchange of geological and calibration data provided for in the Verification Protocol to the TTBT. These data include:

- identification of the test sites and testing areas therein,
- geological and geophysical properties of rocks in which tests are conducted,
- yield, date and location for two "calibration tests" in each geophysically distinct testing area.

In addition, the Protocol obligates the parties to give notification of every nuclear test after it has been conducted.

Similarly, the Peaceful Nuclear Explosion Treaty (PNET) provides for the exchange of the following information for every PNE carried out, regardless of its yield:

- purpose, location, planned date and yield at least 90 days before it is planned,
- description of the technical features of the project, including the type of rock and degree of saturation, and
- after the PNE has been fired, its exact time and actual yield.

For PNE's with yields greater than 100 kt the Protocol provides for on-site verification activities to confirm the geological data and, for groups of

PNE's with aggregate yields above 150 kt, for measurement of the yields by hydrodynamic means.

The PNET also provides for the establishment of a Joint Consultative Commission to handle the exchange of information and to resolve questions. It has generally been assumed that this JCC would also be the mechanism for the exchange of the TTBT data.

Since March 31, 1976, the Soviet Union has carried out over 50 PNEs scattered throughout the Soviet Union. However, none of the above information for these 50 some events has been made available because this Treaty also has not been ratified.

Thus, the U. S. finds itself in the situation that it is observing the 150 kt yield limit of the TTBT, but we can't reach a consensus whether the Soviets are or not. Some believe that the pattern of Soviet testing is consistent with observance of a yield limit; and when proper account is taken of the geological difference believed to exist at the Soviet test sites that this limit is 150 kt. Others reject this analysis, and seismology in general, and believe that the Soviets are systematically cheating by a factor as large as 2 or 3.

Failure to ratify these two Treaties has denied us a considerable body of data which was designed to improve our ability to estimate Soviet yields. Some have argued that the data to be exchanged would not significantly improve our ability to verify Soviet yields since there is no way to verify the accuracy of these data. There is some validity to this criticism and I would like to discuss it for a moment.

I think everyone would agree that it is impossible to believe the "calibration yields" that are to be exchanged. Without some means to verify those yields, they would be useless. I believe this is a major defect in the present treaty. The geological and geophysical data, however, could prove to be useful. Much is already known regarding the geology at the Soviet test site from a variety of sources, including published geological data, satellite reconnaissance, and even from seismic signals originating at the Soviet test sites. I believe it would be very difficult for the Soviets to fabricate a geological framework that was false to a significant degree without it becoming apparent. Having said that, I would like to emphasize that it would still be highly desirable from both a technical and a political viewpoint to have an opportunity to confirm the geological and geophysical data.

Unfortunately, the major question regarding the differences in coupling and transmission of seismic waves from the Soviet test sites as compared to NTS, does not hinge on geological or geophysical properties that are readily measured, but rather on the existence of major differences in the upper-mantle, deep in the earth, under our respective test sites and on their ability to absorb seismic signals.

Thus, I believe the TTBT, as written, contains a number of critical, unverifiable provisions and falls short of providing the verification capability conceived of by those who negotiated it. The first step in enhancing the verifiability of the TTBT would be to consider measures that would rectify these defects.

The most straight-forward approach would be to verify the yields of the "calibration" explosions with on-site hydrodynamic yield measurements. The procedures spelled out in the PNET Protocol, with some minor modification, could well be satisfactory for carrying out these measurements. This could possibly be implemented by carrying out PNEs on the test site whose peaceful purpose is to serve as seismic calibration explosions. I believe procedures could be worked out for selecting the specific sites of the "calibration" explosions to reduce concerns that the locations were picked by the host to be particularly favorable to their interests. Observing the drilling and logging of the emplacement holes for these events, as provided for in the PNET, would serve to provide confirmation of the geological data exchange package in the vicinity of the calibration explosions.

Such an approach would not significantly reduce the random uncertainties associated with the estimates of yields at the Soviet test sites. But, perhaps more important, having verified yield data from the Soviet test sites would determine the validity of the seismic methodology and thus resolve the present major disagreement regarding the existence of a systematic error or bias between the U.S. and Soviet test sites.

This first step would appear to me to be the minimum enhancement that must be taken to rectify the obvious inconsistencies of the TTBT as written. Further steps could be considered that would primarily have the effect of reducing the random errors associated with the yield estimates.

One approach would be the development of methods for use of other seismic waves which would be independent of the one seismic wave presently used. This approach would require no supplemental treaty provisions beyond those needed to implement the first step outlined above for monitoring a 150 kt threshold. It would require a continued program of seismic research focused on this issue to develop these new methodologies. Preliminary work indicates promise for significantly reducing the uncertainty of seismic yield estimates.

An alternative approach to significantly reduce the random uncertainties would be the on-site hydrodynamic yield measurement of all weapons tests above some yield such as 75 kt. These measurements would be similar to those provided for in the PNET except that for weapons tests, which typically have many diagnostic experiments in the emplacement hole, these measurements would be made in a satellite hole near the emplacement hole. This approach would require some restrictions on the experimental configuration of the canisters that contain the nuclear device and the diagnostic components to prevent degradation of the hydrodynamic yield accuracy. Care would have to be taken that these measures didn't impede nuclear test requirements or provide opportunities for revealing classified data.

The implementation of such enhanced verification regimes would significantly reduce the random uncertainties that are associated with yield estimates but no one should believe that they would eliminate concerns about systematic errors and the need to deal with questions of compliance in a statistical framework.

Conclusion

The question of whether to proceed with ratification of the TTBT and the PNET and with what verification regime is, at heart, a political judgment requiring the balancing of a number of issues.

The key issue is the extent to which possible Soviet evasion of the 150 kt threshold within the statistical uncertainties would threaten U. S. national security. Inherent in this judgment is the quantitative element of how uncertain our measurement system is which must be balanced against the qualitative judgment on what risk of detection of an evasion attempt the Soviet Union would be willing to accept.

The obvious value from a national security point-of-view of a very rigorous verification regime with minimum uncertainty must be balanced against the difficulties of negotiating such a regime or, failing negotiation, living with the present verification regime.

My own judgment is that the U.S. should proceed with ratification of the TTBT and PNET but only if, as a minimum step, the U.S. can reach agreement with the Soviet Union for on-site hydrodynamic verification of the calibration yields and on-site confirmation of the geological data called for in the TTBT protocol. Ratification of the TTBT and PNET with such a supplemental verification agreement would eliminate the most serious concern regarding Soviet cheating and bring into implementation of a treaty that provides for substantial excnange of data and on-site verification activities on the soil of each others country.

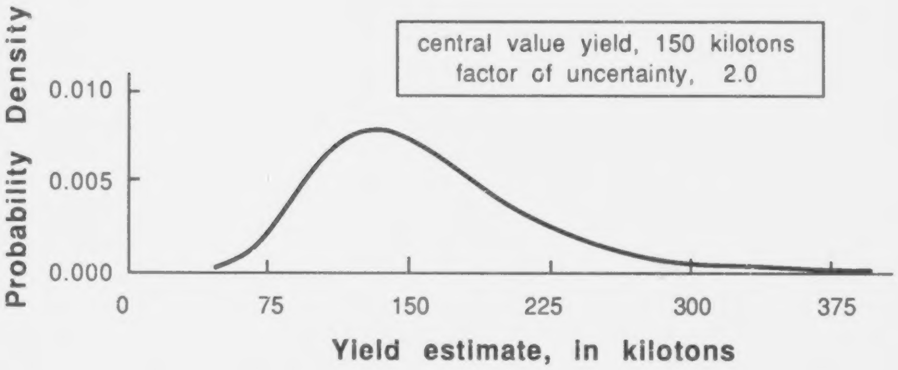
Prepared Statement of Paul G. Richards

Mr. Chairman, members of the Committee, I was asked last week to testify to you on "the state of the art" in seismology, with reference to monitoring explosions. I have taught at Columbia University for 15 years, and am co-author of a two volume textbook entitled "Quantitative Seismology" that has recently been translated into Russian and Chinese. For twenty years I have been familiar with research programs related to seismic monitoring of explosions. In 1984 I began a 12-month appointment as a Visiting Scholar (a William C. Foster Fellow) with the U.S. Arms Control and Disarmament Agency. I am currently a member of the Advisory Panel recently set up to oversee an Office of Technology Assessment study, entitled "Seismic Verification of Nuclear Test Limitation Treaties.

It is generally recognized that in order to monitor compliance with the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty, the principal source of information is seismology. When an earthquake or an underground explosion occurs, waves are set up within the solid Earth. They propagate outwards and away from the source, in much the same way as the sounds I am now making propagate away from my voice box, by spreading as pressure waves through the air in this room. In the case of seismic monitoring, much of the relevant technical details are quite routine and openly known. Of course I don't have time to cover them in this statement, so I would appreciate being able to insert for the record a paper entitled SEISMIC MONITORING OF NUCLEAR EXPLOSIONS. It is from an article I finished last month, which has been accepted for publication in a forthcoming Encyclopedia of Geophysics. This paper may serve as a short primer on relevant technical details.

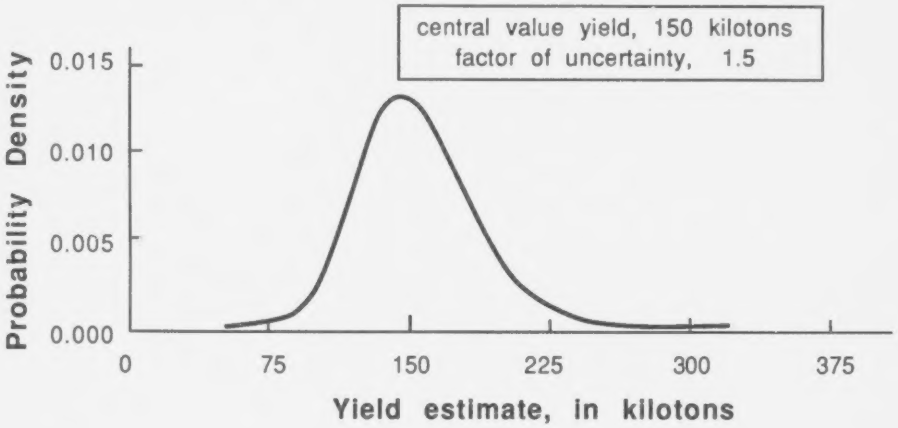
At present, for explosions of concern with respect to the 150 kiloton threshold, a "factor of 2" uncertainty is commonly quoted. By this is meant, that the seismic yield estimate (sometimes called the "central value yield"), when multiplied and divided by 2 (the "factor of uncertainty"), gives a range of yields within which one has confidence that the actual yield really does lie. This level of confidence can itself be expressed as a percentage, usually taken as about 95% in seismology. Some figures are shown on the next two pages, that give the mental images that a scientist uses in characterizing uncertainty. However, a value of 2 for the factor of uncertainty is not a fair summary of current capabilities, because it refers only to one type of seismic method, and for large explosions there are typically three or more independent seismic waves upon which separate seismic yield estimates can be based. If the average of these estimates is taken as the central value yield, with a factor of uncertainty of 2 (at the 95% level) for each of three methods, it is easy to show that the resulting seismic yield estimate has only a factor of 1.5 uncertainty. There may be debate as to whether the available seismic methods are each equally good, and how they should be weighted in coming up with a best estimate using more than one seismic method. My point is simply that for large explosions, which generate a variety of different seismic waves, the factor of uncertainty is less than two.

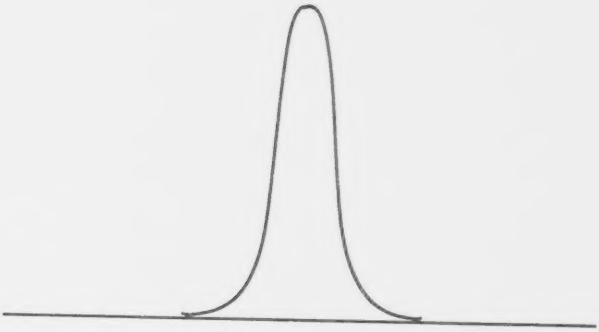
adapted from Congressional Research Service Report No. 86 - 155 SPR
"MONITORING NUCLEAR TEST BANS"
by David W. Cheney



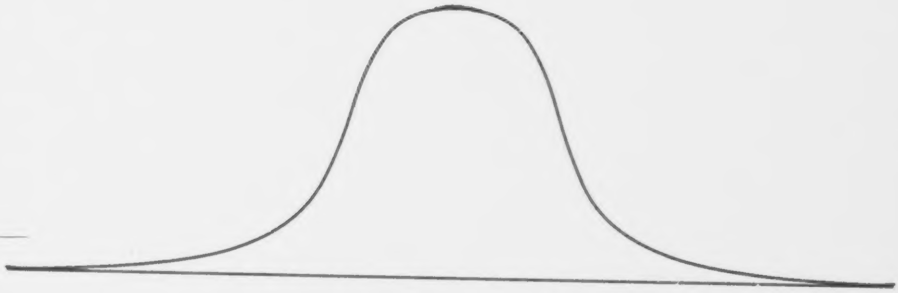
To say that the "factor of uncertainty" is 2, when the central value yield is 150 kilotons, means that there is a 95% probability of the actual yield lying between 75 and 300 kilotons. There is only a 2.5% probability of it lying above 300 kilotons, and 2.5% probability of it lying below 75. These percentages are obtained from the above curve by seeing that the range from 75 to 300 kilotons includes 95% of the area under the curve; above 300, and below 75, each has only 2.5% of the area under the curve.

If the "factor of uncertainty" is only 1.5, then the range of yields (having 95% probability of including the actual yield) is narrower. The percentages are obtained from the following curve:





Accurate



Inaccurate

Interpretation of Seismic Yield Estimates for the largest Soviet Explosions

I recognize that the question of Soviet compliance has to be decided as a political judgement. The way that the technical community can contribute, is to give a best professional opinion on the relevant numbers. For example, we can come up with best estimates for the yield of Soviet explosions, and we have to describe our uncertainty associated with these estimates.

The biggest Soviet explosions in recent years have been in Eastern Kazakh, near the town of Semipalatinsk. There have been many open-literature studies of these events, and typically these papers do show some with yield estimates above 150. But there's a couple of ways to see that this is not the end of the story. For example, consider a program of testing at 149 kt every year. Then, because each seismic estimate is not going to be absolutely accurate, some seismic estimates will come in above 150. In fact, this would be expected to happen, if the Soviets were repeatedly testing right up to the allowed threshold. Another way to appreciate that a few events with seismic yields above 150 does not directly indicate non-compliance, is to consider what would happen if the seismic method were applied to our own test site in Nevada. [This basic idea is described in the Congressional Research Service document cited in the first Figure, above.] Because of the uncertainties, some of the U.S. weapons tests would be estimated, from seismic measurements, to be over 150 kilotons.

Fundamentally, the problem of assessing compliance with a yield threshold will always have this kind of difficulty. That is, the problem is not unique to seismology, nor to 150 kilotons. If a method that had a 1.1 factor of uncertainty were used, and testing was routinely taken up to the threshold but not above, then there would still be a nearly 50-50 probability that the "central value" estimate would exceed that threshold for the largest events.

A slightly related subject is that of a test which indeed does go over the threshold, perhaps because the yield was somewhat larger than planned. How should it be handled? Quoting from a 1982 publication:

> **The technical problems associated with a yield threshold were recognized by the sides in the spring of 1974 during the negotiation of the TTB Treaty. In this context the U.S.S.R. mentioned the idea of some kind of a "mistakes" understanding concerning occasional minor, unintended breaches. Discussions on the subject of such an understanding took place in the autumn of 1974 and in the spring of 1976. The U.S.S.R. was informed by the United States that theunderstanding reached would be included as part of the public record associated with submitting the TTB Treaty to the Senate for advice and consent to ratification. The entire understanding is as follows:**
>
> **Both Parties will make every effort to comply fully with all the provisions of the TTB Treaty. However, there are technical uncertainties associated with predicting the precise yields of nuclear weapons tests. These uncertainties may result in slight, unintended breaches of the 150 kiloton threshold. Therefore, the two sides have discussed this problem and agreed that: (1) One or two slight, unintended breaches per year would not be considered a violation of the Treaty; (2) such breaches would be a cause for concern, however, and, at the request of either Party, would be the subject for consultations.**

The U.S.S.R. was also informed that while the United States would not consider such a slight, unintentional breach a violation, the United States would carefully review each such breach to insure that it is not part of a general attempt to exceed the confines of the Treaty.

The understanding in its entirety was included in the transmittal documents which accompanied the TTB Treaty and the PNE Treaty when they were submitted to the Senate for advice and consent to ratification on July 29, 1976.

[From "ARMS CONTROL AND DISARMAMENT AGREEMENTS,"
1982 edition
published by the U.S. Arms Control and Disarmament Agency]

Monitoring for Possible Future Test Ban Treaties

President Reagan's letter of October 10, 1986, to Senator Goldwater contains the words:

> **"..how one transitions to a total test ban regime is no less critical a concern than verification or any other national security issue related to an eventual implementation of a CTB."**

I was asked a few months ago, by another committee of the Congress, to suggest how monitoring issues might enter into the planning of a new test ban treaty. This question was a stimulus to co-author a paper on the subject, and again I would appreciate a paper being placed in the record of this Hearing. It is entitled TOWARD A NEW TEST BAN REGIME, and it attempts to develop a practical compromise between prompt negotiation of a comprehensive test ban, and the status quo. It describes several technical matters that are relevant to the present debate on the 150 kiloton Threshold Treaties. The paper discusses the technical problems of yield estimation at yields well below 150 kilotons, in the context of a Low Yield Threshold Test Ban Treaty.

Consensus on Technical Issues in Seismology

Although I was asked to characterize the "state of the art" in seismology, I think it may be more important to convey the sense of consensus for that part of the work that is more seasoned. Thus, I have not covered the latest research ideas, because these change all the time. They exist, and are likely to result in new, slightly different, and presumably better seismic yield estimates. But at this stage of debate on the Threshold Treaties it is the methods that have been around a while that matter most. There appears to be a consensus on their qualities. Perhaps one way to see this, is that the seismological techniques most relevant to monitoring Threshold Test Ban compliance have not been presented to the Congress in the last two years as an area characterized by disagreement between experts on technical issues. If there were no consensus, it should not be too difficult to put a few of us seismologists side by side and thus make it visible that consensus is absent. Of course, there have been spokesmen who are not seismologists, who say "seismic yields can be off by a factor of two," but I hope I've indicated that this is an unfair characterization of what it is that the technical community is actually saying.

Seismology is a much larger subject than is generally recognized. Thus, it has been funded at (very roughly) the $10 - 100 million/year level by each of the following Federal agencies: NOAA, NSF, USGS, AID, NASA, BLM, DARPA, NRC, DoE, ONR, and AFTAC. It is supported significantly by certain individual States of the Union, and by several utilities companies. It has been associated with annual expenditures of $3 to 4 billion in recent years by U.S. oil companies (to acquire and process geophysical data, most of it seismic). These figures fluctuate considerably, and of course they have been down in the last two years in the oil industry. About 50 U.S. universities offer graduate degrees in seismology or related areas of geophysics.

Within this large profession, in which many studies of Soviet yields have been made, I say there is now consensus. In particular, the uncertainty in our seismic yields estimates is less than a factor of two.

UCID-20961

NUCLEAR WEAPON R&D AND THE ROLE OF NUCLEAR TESTING

Paul S. Brown

January 1987

Lawrence
Livermore
National
Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.

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Nuclear Weapon R&D and the Role of Nuclear Testing

Our national policy with respect to nuclear weapons is one of deterrence. For deterrence to be a credible policy, the U.S. must maintain an effective, survivable, and varied nuclear force to convince any adversary that we could retaliate with nuclear weapons in the event of aggression against us or our allies.

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The global strategic balance is constantly changing. New technologies and developments can weaken the credibility and survivability of the U.S. deterrent; they may also enhance credibility and survivability. The tension between these two effects leads to a dynamic deterrent relationship among nations. In turn, this can lead to changes in mission requirements for our nuclear forces or to changes in delivery systems, which might require the modification of existing nuclear warheads or the development of new warheads.

For example, Soviet missile accuracies are constantly improving, putting our land-based missile force at ever greater risk from an enemy first strike. Some day, the Soviets may develop the capability to achieve even greater accuracy by using satellites to provide terminal guidance for their warheads. We can use a number of technological solutions to enhance the survivability of our land-based missiles, some of which are new systems that require new warheads. For example, we might develop a ballistic missile defense system to protect portions of our land-based missiles, thereby ensuring that enough missiles would survive a first-strike attack to provide a retaliatory capability. Hardening our missile silos, deceptive basing, and deploying mobile land-based missiles are other solutions.

The mobile small intercontinental ballistic missile (SICBM), sometimes called the Midgetman, is a mobile system that is currently of great interest to the defense community (Fig. 1). To enhance its mobility and increase its survivability, the SICBM must be lightweight, which, in turn, limits its throw-weight (payload) capability. Because the SICBM may have to travel over rough roads or cross country, its warhead must be designed to withstand long-term vibration environments. In addition, because of potential access by the public to deployment areas, its warhead must have appropriate safety and security features. There is also an ongoing debate as to how large the SICBM should be and whether it should carry a single or multiple warheads. The ultimate choice of a warhead for the SICBM awaits resolution of this debate.

The choice of warhead for the SICBM illustrates some of the considerations involved in the acquisition of a new weapon system. The Department of Defense (DOD) specifies the requirements for the new mission and new delivery system. The Department of Energy (DOE) weapons design laboratories (Livermore and Los Alamos, in collaboration with Sandia) are asked to state how they would meet the warhead requirements for the new system. Sometimes it is possible to meet the requirements by modifying warheads from existing systems, but, more often than not, a new warhead is required. (Warhead development and production costs are typically only 10 to 15% of the total cost of the delivery system.)

The weapons design laboratories also have the continuing responsibility to research new technologies that might improve our deterrent capability or even alter our approach to deterrence. On occasion, they conceive new concepts or pursue novel physics principles that have potential application to new weapon systems. If the proposed concepts have merit, they may eventually be developed into an actual weapon system.

A significant motivation for exploring new concepts is to avoid technological surprise and to find out what is possible in weapons technology. If a new technology is possible for the U.S., then it is also possible for others. Our deterrent posture would be jeopardized if our adversaries were to develop a new and particularly threatening capability that put at risk a large fraction of our deterrent capability. For example, LLNL is engaged in an active research program to study nuclear-driven directed-energy weapons, such as the x-ray laser, in support of the Strategic Defense Initiative (SDI). A most important reason for doing this research is to assess the threat that U.S. space-based defenses and other military space assets might face should the Soviets deploy such a weapon.

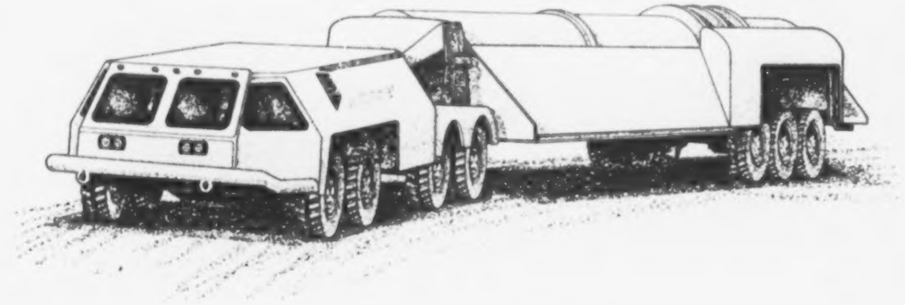
Once the requirement for a new weapon system is spelled out, the DOE design laboratories undertake extensive studies to determine its feasibility (see the article on p. 19). After feasibility is established, a complex iterative process ensues, involving the legislative and executive branches of the U.S. government, before approval is finally granted for the development and ultimate production of the weapon.

Military Characteristics of a Warhead

The DOD prepares a set of military characteristics (MCs) that defines the requirements for the nuclear warhead. The MCs specified

Fig. 1

The survivability of our strategic forces will be improved by deploying small intercontinental ballistic missiles (SICBMs) in hardened mobile launchers. An attack on hardened launchers, dispersed over a large area, would require an unfavorable exchange ratio to achieve high confidence in destroying a significant fraction of these targets.



future weapon scientists, who might lack the necessary expertise, to make decisions as to whether changes can be made in the production process without adversely affecting the performance of the weapon. The challenge faced by the weapon designers, therefore, is to develop warheads that minimize the possibility or impact of mistakes in future versions of the design.

The availability of organic materials changes with time. Some compounds have been found to be carcinogenic and are no longer produced. Other product changes occur as a result of economics and product improvements. High explosives are an example of organic materials that are particularly difficult to replicate. We may not be able to reproduce the older production processes for the explosive, some of which involve as many aspects of art as they do of science. Replacing an older explosive with a new one is actually a significant design change that requires nuclear testing.

The chemically reactive nature of many components used in nuclear weapons sometimes results in chemical incompatibilities that can lead to early degradation in the stockpile. New technology, instead of replication, often allows designers to use fewer nuclear materials or alternate materials or to relax certain specifications to reduce costs. However, some of these changes may need to be verified in a nuclear test, and expert scientific judgment is required to determine which changes can be safely made without nuclear testing and which require nuclear tests.

Identical replication of a troublesome system would also invite recurrence of a given problem. The fact that modern safety and security features are not present in older systems is noteworthy. The rejuvenation of an older system presents an opportunity to add these important features to the stockpile. Exact replication would preclude improvements in the design or fabrication of a weapon, even though the reasons advanced for such improvements are often driven by compelling economic factors or by safety and security considerations. Such improvements often involve design changes that affect the performance of a weapon, requiring a nuclear test for certification.

Finally, we have found through experience that we cannot specify all the subtle manufacturing criteria that affect nuclear weapon performance. Nuclear proof tests are required to verify the manufacturing process for the weapon. Proof tests are especially important when production of a warhead lasts for many years, during which time subtle changes can creep into the manufacturing process. In a recent example, the use of preproduction hardware with specifications identical to those to be used in the production line, but tailor-made for a nuclear test, significantly affected the yield of a nuclear device at the Nevada Test Site (NTS).

Modernizing for Improved Safety and Survivability

The safety and security record of the U.S. stockpile is excellent. This success is due, in large part, to our continuing efforts to design safe and survivable warheads and to modernize the stockpile by incorporating new safety and security features into new and existing weapons. Only one-third of our stockpiled weapons have these modern safety and security features.

Safety

No weapon accident has ever produced any nuclear yield. In two accidents, however, the high explosive in the weapons reacted violently, dispersing plutonium in the vicinity of the crashes. In 1966 a B52 bomber carrying nuclear weapons crashed in Palomares, Spain, and in 1968 another crashed in Thule, Greenland. At Palomares, the high explosive detonated; at Thule, evidence indicates that the explosive underwent deflagration or rapid burning. Because the devices had been designed and tested to be safe against high-explosive initiation at a single point, there was no nuclear yield. However, cleanup of the plutonium to acceptable levels was extremely expensive, and the political consequences of these accidents were quite serious.

Until these two accidents occurred, it was possible for our B52 bombers to remain on continuous airborne alert. However, in part because of the plutonium dispersal experienced at Thule and Palomares, it was deemed that the risk of plutonium dispersal was too great, and continuous airborne alerts were discontinued.

In September 1980, a B52 caught fire on the tarmac at an Air Force base in the continental U.S. Figure 2a is a photograph of the burning B52 taken at night; Fig. 2b shows the aircraft in the morning after the fire was extinguished. The fire occurred in one of the engines while the wind was blowing away from the fuselage of the plane, as shown by the blackened mark on the runway. Had the wind been blowing toward the plane (the normal wind direction for that time of year), the fuselage would have caught fire.

Our B52 bombers are normally parked in "strip alert" on similar tarmacs at various Air Force bases. These bombers carry live bombs and short-range attack missiles containing a type of sensitive high explosive similar to that involved in the accidents at Thule and Palomeres. If these planes were to catch fire, it is possible that either the explosive in the bombs would detonate and burn or that the weapons would be damaged in the fire. In either event, plutonium dispersal would be a threat.

To avert such problems, Livermore and Los Alamos scientists developed a new explosive, TATB or triamino-trinitro-benzene, that is now entering the stockpile in a variety of weapon systems. TATB is an insensitive high explosive (IHE) and is extremely difficult to detonate in the event of an accident, such as the impact of a stray bullet or an airplane crash. Its use would have precluded plutonium dispersal in the Thule and Palomares accidents.

Another instance illustrating the dangers of potential detonation occurred with a Titan missile in Damascus, Arkansas, in September 1980, when the rocket propellant in a Titan missile exploded (Fig. 3). The warhead was thrown clear of the missile and, fortunately, the high explosive (conventional, not insensitive) did not detonate. The Titan missile is now being retired. The new Peacekeeper warhead will have IHE and thus will not be vulnerable to such an accident, illustrating again the importance of weapon modernization.

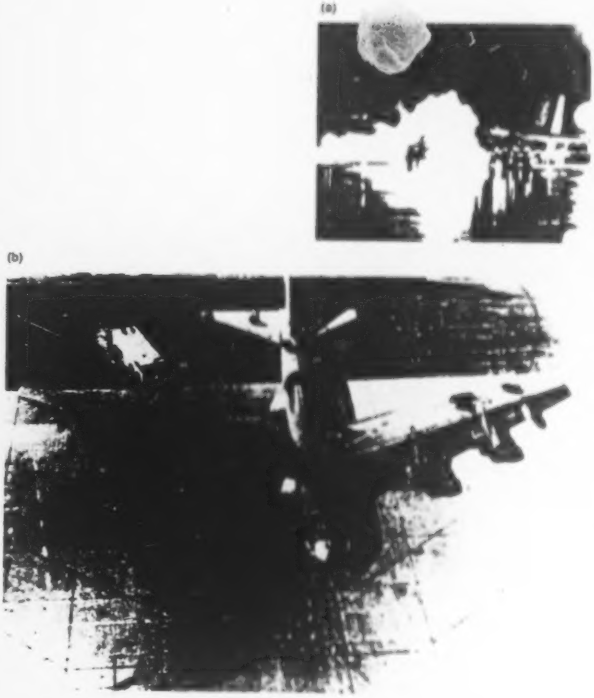


Fig. 2

In September 1980, a B52 sitting on the tarmac caught fire at an Air Force base in the continental U.S. (a) The burning B52 at night. (b) The same B52 on the morning after the fire in one of the engines had been extinguished. The wind was blowing away from the fuselage, as shown by the blackened area on the runway. Had the wind been blowing in the direction normal for that time of year, the fuselage probably would have caught fire. Our B52 bombers are usually parked in "strip alert" at similar bases. If the planes were to catch fire, the high explosive in any bombs on board could conceivably detonate or burn, which, in turn, might lead to plutonium dispersal. The use of insensitive high explosive can eliminate the hazards of such plutonium dispersal.

Survivability

The SICBM, the ground launched cruise missile (GLCM), and the air-launched cruise missile (ALCM) are examples of weapon systems that provide greatly increased survivability to enemy attack. The GLCM and ALCM, with warheads designed by Livermore and Los Alamos, respectively, are now in stockpile. The SICBM is still in development.

In the GLCM and the SICBM, survivability is enhanced by mobility of the weapon. This mobility requires that both warheads use IHE to provide safety. The ALCM warhead also uses IHE. The ALCM is carried by our B52 and B1 bombers; it enhances the survivability of our second-strike force by allowing the bombers to launch their weapons before they encounter Soviet air defenses.

The GLCM warhead also has enhanced security features that deny use of the weapon should it fall into enemy or terrorist hands. The GLCM and the Peacekeeper warheads also have features that increase their safety in the event of a fire. These features retard possible damage, allowing more time to extinguish the fire and thereby reducing the risk of plutonium dispersal.

Survivability and Nuclear Effects Testing

A very important part of the U.S. nuclear testing program, and a responsibility of the Defense Nuclear Agency, is to test the effects of nuclear weapons on a vast array of military equipment. Of particular concern are the nonnuclear components of our strategic weapon systems, warning sensors, and communications equipment which might have to function in a nuclear environment. As in the testing of nuclear weapons, we are frequently surprised by the results of nuclear effects tests on equipment that has previously been subjected to nonnuclear tests. Often, the nuclear tests reveal changes that must be made, and additional nuclear tests usually are required to certify the survival and proper functioning of these systems in a hostile nuclear environment.

Reduced Stockpile Yield and Number of Weapons

It is often erroneously believed that efforts to modernize the U.S. nuclear stockpile have led to an escalating yield and number of weapons. In fact, the exact opposite is true. Figure 4 shows the relative total yield of the U.S. stockpile from 1955 through 1985. This figure reveals that the total yield of the U.S. stockpile has been reduced fourfold from its peak value in the mid 1960s. Modernization has played a major role in reducing the yield of the stockpile. This reduction is largely the result of increased accuracy of the delivery systems, which has made it possible to develop and deploy warheads of lower yield. Figure 5 shows the relative number of U.S. nuclear weapons versus time; the number of weapons in the stockpile at the end of 1985 is about 25% lower than the peak value.

LLNL's Weapons Program

As one of the nation's two nuclear design laboratories, LLNL plays a vital role in designing and maintaining the U.S. nuclear deterrent. As can be seen from the discussions above, the responsibilities and challenges involved are significant. To meet them, the Laboratory's Weapons Program has defined four broad missions.

The first and most important is to ensure that the weapons in the stockpile and those now entering the stockpile are safe and reliable. We have responsibility for monitoring the LLNL-designed weapons in the stockpile. Confidence in the reliability of the weapons in the stockpile is maintained by the stockpile surveillance program, by quality assurance and reliability testing of nonnuclear components, and by nuclear testing of warheads or related devices. Laboratory weapons scientists conduct about two stockpile confidence tests each year, during which either war reserve components or weapons from the field are returned for testing at the NTS. These tests are not merely simple experiments to verify yield; rather, the devices are thoroughly diagnosed to identify potential problems that could affect the physics performance of the weapon. Serious stockpile problems have been revealed by these tests, and nuclear tests have been required to resolve them.

The second mission is to develop warhead options for new weapon systems. In developing warheads to meet DOD's requirements, we place considerable emphasis on improvements in safety, security, survivability, and military

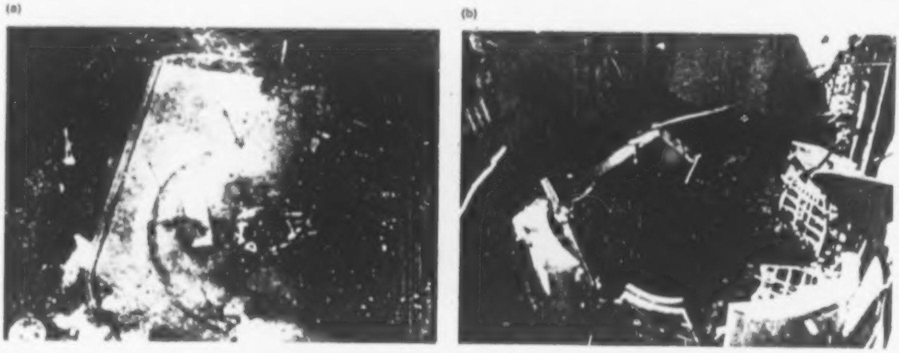


Fig. 3

In Damascus, Arkansas, in September 1980, the rocket propellant in a Titan missile exploded, throwing the warhead clear of the missile. The aerial view (a) and photograph of the silo doors (b) reveal the force of the explosion. Fortunately, the high explosive in the warhead did not detonate. The Titan is now being retired, and there will no longer be a risk from this weapon system. The warhead in the new Peacekeeper missile contains an insensitive high explosive and will be invulnerable to such an accident.

effectiveness. A number of nuclear tests are conducted each year as part of our ongoing weapon development program. These tests also contribute to our stockpile maintenance efforts by providing actual experience for scientists who must make judgments about the stockpile and by adding to our data base of nuclear device performance.

A third mission is to maintain expertise in the area of nuclear weapon design and development. This enables us to improve our understanding of current weapon systems and provides a technology base for future options as dictated by national security needs. Weapons expertise is of great importance in providing insight into what is technologically possible for our potential adversaries. Experienced personnel are essential to this effort. Many design and stockpile reliability decisions rely heavily on the technical judgment of the weapons scientist, judgment that can be derived only from experience.

The fourth mission of the Laboratory's Weapons Program is to provide technical support for the nation's objectives in arms control and verification. Arms control is not a separate effort at LLNL; rather, it is an integral part of the Weapons Program. The same expertise that is used to develop weapons is directly applied to their control. We regularly serve as advisors to various national and international committees on the technical merits and verifiability of arms control proposals, and we perform technical studies on issues related to arms control, national security, and arms race and crisis stability.[1]

Nuclear Testing and Stockpile Reliability

Nuclear weapons are complex mechanisms made of highly reactive materials and sometimes, of necessity, they include materials with limited lifetimes. Because of these characteristics, changes have occurred in stockpile weapons that raise the question of whether a weapon would perform as designed. Figure 6 shows a weapon part in which extensive corrosion was observed during routine stockpile surveillance. In this case, designers determined that the corrosion would not adversely affect the operation of the weapon. They were able to make this assessment with confidence because they had developed technical judgment based on years of experience in conducting nuclear tests that permitted them to evaluate what factors mattered.

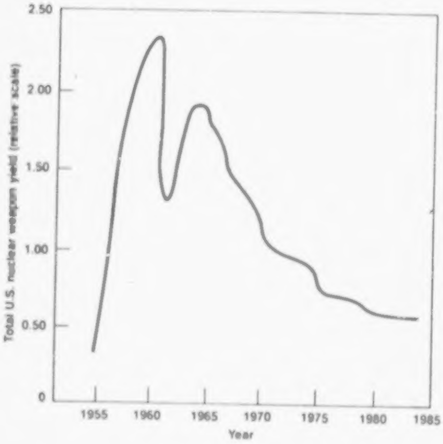


Fig. 4

Total yield of the U.S. nuclear weapon stockpile (relative to a value of 1.0 for the year 1972) from 1955 through 1985. This curve shows that the total yield in the stockpile has been reduced fourfold from its peak value in the mid-1960s, demonstrating the role that modernization has played in reducing the yield of the stockpile.

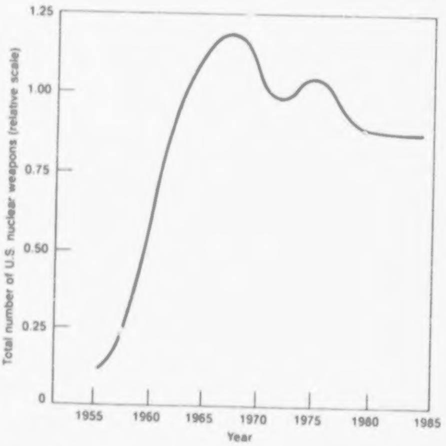


Fig. 5

The number of total U.S. nuclear weapons in the stockpile inventory (relative to a value of 1.0 for the year 1972) from 1955 through 1985. The total number of weapons in the stockpile at the end of 1985 was 25% lower than the peak value in the 1960s. These data demonstrate that, contrary to the commonly held belief, modernization has led to fewer total nuclear weapons in the stockpile.

Nuclear tests, however, have been necessary to fix problems. Approximately one-third of all modern weapon designs placed in the U.S. stockpile required and received post-deployment nuclear tests for resolution of problems. In three-fourths of these cases, the problems were discovered only because of the ongoing nuclear testing. A number of problems arose because of the nuclear test moratorium of 1958-1961, clearly illustrating the difficulties that can arise in the absence of nuclear testing.

Lessons from the Test Moratorium

From 1958 to 1961, the U.S. and the Soviet Union observed an unwritten agreement not to test nuclear weapons. In effect, there was a *de facto* test ban for three years. However, in September 1961, the Soviets suddenly resumed testing with an extensive and well-prepared series of events, surprising us by the extent of their test series and the magnitude of their yields. The U.S. followed suit as best it could, but testing initially was on a very limited scale and required a long time to come up to speed.

The U.S. experienced a number of surprises when certain weapon systems developed during the moratorium failed to perform as predicted when they were finally tested. The failures were due to such factors as a lack of understanding of the fundamental physics of nuclear explosives, inadequate knowledge of the environments in which weapons might be required to survive, improper approaches to weapon safety, and, most important, unjustified confidence bred by nonnuclear experimentation and unverified calculations. If testing had not resumed, some of the warhead designs that entered the stockpile would not have worked.

Problems with the W52 High Explosive. The W52 was the nuclear warhead for the Army's now-retired Sergeant surface-to-surface missile. In 1959, a warhead was being readied for production when two explosive accidents occurred at Los Alamos, killing four people. The explosions were due to the unexpected susceptibility to accidental detonation of the high explosive used in the W52's fission trigger.

Los Alamos had to change the explosive used in the W52 to a safer and less sensitive explosive, which was also somewhat less energetic. This decision was made during the moratorium, when the new design could not be verified in a nuclear test. The redesign was based on nonnuclear hydrodynamic tests and on computer design calculations.

Because of the high confidence that Los Alamos scientists had in their redesign, they did not immediately test the W52 when the moratorium ended in 1961. The W52 entered the stockpile in April 1962. When Los Alamos finally tested the device in early 1963, the W52 gave only a small fraction of its expected yield. The weapon, as delivered, was militarily unacceptable.

Los Alamos scientists made a rapid redesign. Within three months of the test failure, they successfully conducted a nuclear test of the new design, which was subsequently incorporated into the stockpile. The difficulties with the W52 are an especially dramatic illustration of the limitations of nonnuclear experiments and computer calculations in the evaluation of seemingly moderate changes in warhead designs.

Unexpected Aging in the W45. LLNL scientists developed the W45 in part during the moratorium. The W45 was the warhead for the now-retired Little John missile and atomic demolition munition (ADM); the W45 is still used in the Terrier missile. When the W45 entered the stockpile in 1962, it had not been tested to simulate certain effects of stockpile aging. Because of confidence in our calculations and other priorities, we waited until the mid-1960s to test the effect of what we expected to be small aging changes. The result was a surprise: the test gave only one-half the expected yield.

Design changes were made to the W45, and these were verified in a series of five nuclear tests. It was only on the basis of these tests that we

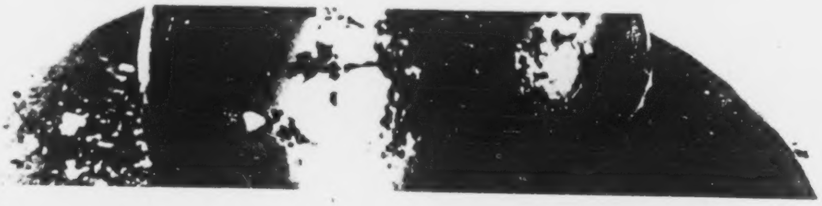


Fig. 6

Extensive corrosion was observed in this weapon part during routine stockpile surveillance. In this example, LLNL designers determined that the corrosion would not adversely affect operation of the weapon. They were able to make this assessment with confidence on the basis of technical judgment developed over years of experience in conducting nuclear tests.

could guarantee the performance of the various versions of the W45 at different stockpile ages.

Los Alamos also had similar problems with aging that affected a number of stockpile designs. These problems have been corrected, but nuclear testing was essential to their resolution.

Problems with More Modern Weapon Systems

Although the problems with the W52 and W45 arose at the time of the test moratorium, even modern weapon systems have had problems that have been identified and resolved only by nuclear testing. In one case, deterioration of a weapon component was observed during normal stockpile surveillance, and the weapons designers judged the problem to be serious enough to require a design modification. The component was redesigned and a nuclear proof test was required to certify that the new design would perform properly.

In another case, a final proof test of a stockpiled weapon, tested under certain aging conditions to be expected in the stockpile, gave an unexpected reduction in yield. The weapons designers suspected that various engineering design features incorporated in the weapon after the physics-design nuclear tests were successfully completed may have had an adverse effect on the operation of the weapon. Design changes were made, and a second proof test was conducted to verify that the weapon would meet its military requirements.

In a third case, a final proof test at the weapon's specified low-temperature extreme was done just after deployment of the weapon had begun. The test results were a complete surprise. The device gave only a small fraction of its expected yield. The weapon had been tested extensively in nonnuclear hydrodynamic tests and was even tested at the low-temperature extreme with no indication of trouble. Thus, on the basis of the nonnuclear testing and previous successful nuclear tests, the weapons designers had every reason to believe that the low-temperature proof test would produce the predicted yield. After extensive post-test analysis, the design was modified and another low-temperature nuclear test was performed. The test of the modified design was successful, and confidence was established that the warhead would operate properly over its entire temperature range. The production specifications were changed, and the approved warhead entered the stockpile.

This last example illustrates yet again the inadequacy of nonnuclear testing and the need for nuclear tests. Without the low-temperature nuclear test, the weapons designers would have judged, on the basis of the nonnuclear tests, that the system would perform properly. However, in actuality, the deterrent capability of this particular weapon system would have been in question under environmental conditions that could have been fully expected to occur. As a result of the experience with this particular warhead, similar low-temperature nuclear tests have been done for several other weapon systems.

Nuclear Testing and Weapon Design

The design of a weapon is a complex, iterative process. We start by simulating experiments on high-speed computers. However, such simulations encounter difficulties in matching the real behavior of a nuclear device, in part because of their use of a largely theoretical and phenomenological data base that contains considerable uncertainties.

Nuclear explosions involve extreme conditions—temperatures of millions of degrees, velocities of millions of kilometres an hour, and time scales as short as a few billionths of a second. The physical conditions in a nuclear explosion simply cannot be simulated in full extent or detail in nonnuclear experimental facilities. Accordingly, we must verify our calculations with actual nuclear tests.

A successful nuclear test of a physics device is not equivalent to successful development of a new weapon. A physics device is not a weapon. A weapon must be able to withstand extreme accelerations and environmental conditions. It must have structural supports, arming and firing mechanisms, and engineering design features that can significantly alter its physics behavior. Indeed, our experience with nuclear tests indicates that seemingly unimportant factors, such as chemical impurities, joints and other fabrication features, temperature extremes, and aging effects, can have a major effect on the behavior of a weapon.

Future Directions in Weapon Design

In addition to improved safety, security, and survivability, increased military effectiveness is another major concern in the development of new weapons. Several new weapon concepts are currently being investigated at LLNL that could provide substantial benefits to the U.S. deterrent capability.

Earth-Penetrating Warhead

The earth-penetrating warhead (EPW), shown in Fig. 7, can provide a greatly improved capability for destroying hardened military targets with substantial reductions in yield. It has been argued that hard-target capability can be destabilizing. However, such capability can have considerable deterrent value when it holds at risk assets that an adversary highly values.

By penetrating a short distance into the ground before it detonates, the EPW couples a much greater fraction of its nuclear yield into ground motion. To deliver a given shock-wave intensity to an underground target, an EPW requires considerably less yield than a surface-burst weapon. Although for a given yield, the EPW is heavier than a surface-burst warhead, since it must be robust enough to withstand the intense stresses of earth penetration, the overall gain in the military effect for a given warhead weight is substantial.

Nuclear Directed-Energy Weapons

Other new weapon concepts include nuclear directed-energy weapons (NDEW), such as the x-ray laser. These weapons are being developed in support of the Strategic Defense Initiative (SDI). Although the primary SDI emphasis is on nonnuclear defensive weapons, it is important to understand what can be achieved with NDEWs. The most important reason for doing research on NDEWs is to assess the threat that U.S. systems might face from the Soviets, should they deploy such a weapon. For example, available evidence indicates that the Soviets have had a very active x-ray laser research program, although we do not know if they have succeeded in developing an effective x-ray laser weapon. NDEWs like the x-ray laser might be extremely capable as a counter to space-based defenses or other military assets in space, and it is important to determine what is technologically possible in this area.

In addition, although it is desirable for a defensive system not to rely on nuclear weapons, NDEW concepts serve as a hedge in the event that nonnuclear technologies are not successful. NDEWs could have a significant advantage because they employ the most concentrated energy source available and have advantages in weight and launching costs.

NDEWs can provide a useful complement to nonnuclear defensive weapon deployments. Nonnuclear defensive weapons, which attack targets sequentially, are most stressed by salvo attacks, in which their ability to rapidly acquire, track, and destroy targets is strained. NDEWs, however, are expected to have much higher intensities than nonnuclear directed-energy weapons plus the capability to attack many targets simultaneously. Accordingly, NDEWs force the enemy to spread out its offensive. The result is similar to that achieved by tactical nuclear weapons in Europe, where their possible use deters the massing of conventional Soviet forces, thereby enhancing the ability of conventional defenses to defeat an aggressor.

Nuclear Testing and Technical Judgment

Our experience with the 1958–1961 testing moratorium highlights the uniqueness of the overall process of weapons design and certification. Certification is a guarantee that the weapon will meet the DOD-specified military characteristics. Weapons designers cannot certify nuclear performance on the basis of nonnuclear experiments alone. They cannot model with computers all of the complex physical processes to be able to predict nuclear warhead performance with confidence. Nuclear warheads cannot be "thoroughly" or statistically tested. As a result, the functional capabilities of nuclear explosives cannot be fully established without resorting to a strong dependence on the scientific judgment of the weapons designer.

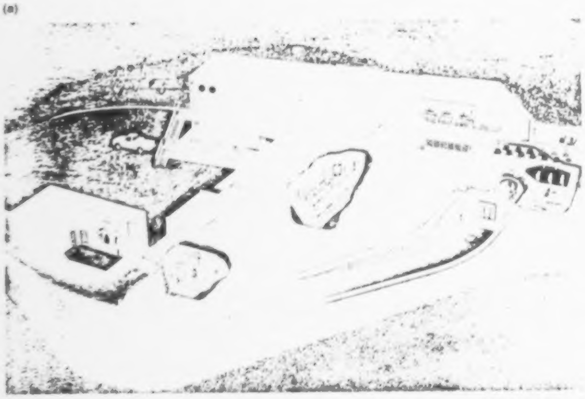
Assessment of a weapon design rests ultimately on scientific judgment based on nuclear test experience. This judgment takes considerable time to develop, is cultivated by the application of theory and calculation to device design, and is continually refined on the basis of data from nuclear tests. Removing the confirmation provided by test results, as happened in 1958–1961, results in the overextension of judgment and in reduced credibility of the nation's deterrent.

Because of the large number of nuclear tests that would be required, it is not feasible to obtain statistically significant data on a given nuclear system. The variability of a system's nuclear performance with changes in production tolerances, environmental

Fig. 7

Photograph of a mock earth-penetrating weapon (EPW) fired from a cannon into the ground at Site 300. The structural integrity of the warhead has been maintained despite the intense stresses experienced by the warhead during penetration into the ground.

conditions (e.g., temperature extremes), hostile environments (as are encountered in antiballistic missile engagements), and aging effects must be simulated with analytical, computational, and phenomenological models. The relevance and completeness of such models are based on the professional judgment of scientific personnel involved in the actual physics, design, and analysis of nuclear warheads. This judgment is aided and constrained by experimental data from testing actual nuclear devices and by data from physics experiments at NTS in the applicable temperature and density regimes. Significant amounts of physics data are derived from actual nuclear tests.



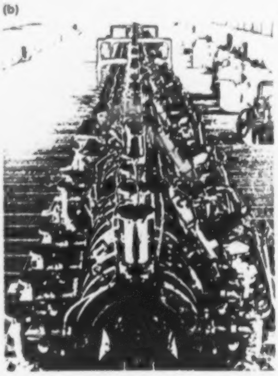


Fig. 8

Overall view of the FXR facility (a), showing the control room, the electronics corridor, the electron source, the chain of accelerator modules, the tungsten target, the firing table and film cassette, and the optics room in which optical records of the implosion are made. The interior of the FXR facility (b), showing the electron beam pipe and beam accelerator modules. The FXR produces fast, intense x-ray pulses that yield high-resolution photographic images of rapidly moving parts inside dense, imploding devices. The devices tested at Site 300 contain inert (nonfissile) material. A goal of our research with the FXR is to gain information during the implosion of a device to complement similar information gathered from nuclear tests.

Preparations for a Cessation of Testing

The U.S. policy of deterrence is based on reliable and effective nuclear weapons. A long-term cessation of nuclear testing would place that deterrent capability in jeopardy. Even under such conditions, however, the Laboratory would have to do its best to ensure the reliability of the nuclear weapons. Accordingly, we have long been concerned with how we could carry out our responsibilities under treaty limitations such as those proposed for a comprehensive test ban (CTB).

Since the 1958–1961 nuclear test moratorium, the Laboratory has been aware of the potential impact of a CTB. Assessments by the Laboratory of the consequences of a CTB have been requested by the U.S. government on many occasions. What will be the Laboratory's ability to carry out its responsibilities if testing is prohibited? It seems likely that, at the very least, these responsibilities will include ensuring the reliability of the existing stockpile, assessing changes in weapons caused by stockpile aging, and assessing corrections of potential problems. It also appears likely that under such a ban, many of our responsibilities could not be met.

We have already discussed changes in weapons design that are dictated by safety and security considerations, use of new materials, new configurations, or new military requirements. Not all such changes require certification by full-scale nuclear tests, but all rely on data obtained in nuclear tests and, most critically, on the judgment and insight that scientists and engineers acquire on the basis of such data. Under a CTB, experimental data could no longer be obtained from testing, the pool of experienced specialists would decline, and the skills of those that remain would diminish.

There is no satisfactory way to solve these problems. They may be alleviated to some extent by such measures as:

- Improving our understanding of present nuclear designs, including such basics as equations of state, opacities, radiation transport, and instabilities, by current nuclear tests and other means.
- Placing increased emphasis on the use of supercomputers and numerical models and on the vigorous development of advanced computers.
- Taking deliberate steps to maintain the capability to produce old weapon designs.
- Acquiring experimental facilities to augment our current nonnuclear testing capability.
- Designing weapons that would be even less likely to suffer material degradation than current designs or that could be modified if need be with less uncertainty about performance. There would, of course, be costs in weight, size, use of special nuclear materials, and military effectiveness with such designs.

The first three approaches are being pursued vigorously. We regularly conduct weapons physics experiments at the NTS as part of nuclear tests scheduled for other purposes. Since 1981, one or two LLNL tests per year have been dedicated to weapons physics research. The knowledge gained from those tests has already permitted us to develop more conservative and reliable designs. We are pursuing weapons physics programs using our experimental facilities at Site 300. In addition, the flash x-ray (FXR) facility (Fig. 8) and the Nova laser facility (Fig. 9) have greatly augmented our nonnuclear testing capabilities.

The Laboratory is constantly acquiring the most advanced supercomputers available. The Livermore Computer Center currently has two CDC 7600 computers, four Cray-1 computers, and one Cray-XMP/48. Much research is devoted to developing improved computational methods to make optimum use of advanced computer architectures and to improve the accuracy of the physics models in our weapons design codes.

Scientists are constantly challenged by the need to understand theoretically the complex physical processes they observe, and ordinarily this drive would be sufficient justification for doing research. Such an understanding is not necessarily essential to guarantee the continued reliability of nuclear weapons, so long as nuclear testing is possible. However, in the absence of nuclear testing, accurate theoretical understanding becomes even more important and provides the major motivation for the research.

In order to maintain the capability to remanufacture weapons, we are placing major emphasis on 25-year objectives, materials compatability, and engineering durability. We also rigidly document production procedures and materials. We could implement further steps, such as continuing production of older weapons at a low rate.

Repeated examination of various nonnuclear experimental facilities has not revealed any that could take the place of nuclear testing. Facilities that we can now envision for the future do not come close enough to simulating the conditions in a nuclear explosion. However, they can provide some relevant weapons physics data, help experimenters maintain some level of relevant skills, and provide a test bed for weapons designers to verify some theoretical aspects of weapons physics.

Examples of existing facilities that would be of some use in the event of a CTB include the FXR and other facilities at Site 300 as well as the Nova laser. We expect, however, that

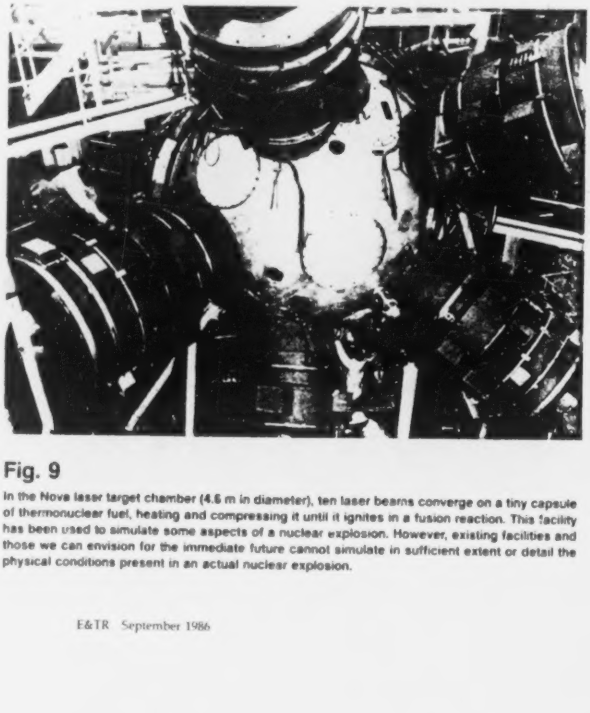


Fig. 9

In the Nova laser target chamber (4.6 m in diameter), ten laser beams converge on a tiny capsule of thermonuclear fuel, heating and compressing it until it ignites in a fusion reaction. This facility has been used to simulate some aspects of a nuclear explosion. However, existing facilities and those we can envision for the immediate future cannot simulate in sufficient extent or detail the physical conditions present in an actual nuclear explosion.

major expensive extensions of these facilities would be required to significantly enhance our ability to make judgments on the basis of nonnuclear testing alone. We are also constructing the High-Explosive Applications Facility (HEAF), which will provide a valuable test bed for high-explosive research. A High-Gain Test Facility (HGTF), using a multimegajoule laser for research on inertial confinement fusion (ICF), would provide much more intense conditions than those available with the Nova facility. The HGTF would allow us to make studies on 1000-MJ ICF capsules. Such yields would produce conditions that would be more relevant to some aspects of nuclear weapons design and diagnostics and would provide a source for some tests on military vulnerability, lethality, and exposure.

A current research program that would help to maintain skills is the development of advanced conventional munitions. Work on such munitions uses many of the same technologies (particularly hydrodynamics, material science, high-explosive chemistry, and high-speed diagnostics) that are involved in development of the fission triggers for nuclear weapons.

The last approach often mentioned to alleviate the impact of a ban on nuclear testing would be to design and manufacture weapons that are less likely to suffer degradation. This would be expensive and quite difficult to pursue because of the configuration of the present stockpile and delivery systems. For example, larger fission triggers are seen by some as less demanding. However, incorporating them in a weapon system would force the concomitant design and use of larger, more expensive missiles and submarines. Thus, there would have to be changes in the priorities of the MCs for future weapon systems. In addition, as history has shown, we often cannot judge ahead of time which components will degrade.

If the specified military characteristics were to change, we might be forced to give up certain improvements in weapons technology that have led to advances in safety, security, survivability, and military effectiveness. Without conducting a detailed study of each proposed new weapon system, we could not know what specific technological improvements would have to be sacrificed in any one system. For example, we might forgo the use of IHE in favor of conventional high explosive. Because IHE is more difficult to detonate, systems that employ IHE are apt to be more sensitive to certain effects of stockpile aging.

The size and weight of warheads might also have to be increased. We have learned from experience that larger systems are less prone to parametric design changes and, for this reason, would be expected to be less prone to the effects of stockpile aging. The increased size and weight of the warhead could also generate the need for larger missile systems.

Similarly, the more nuclear material, such as plutonium and tritium, that a weapon contains, the more robust it normally is to parametric changes and consequently to the effects of stockpile aging. This could entail the use of more nuclear material initially or could lead to more frequent change of tritium components (tritium has a 12-year half-life), with increased operational costs.

Other improvements that might be relinquished include certain built-in security and construction features that allow weapons, such as EPWs, artillery shells, and lay-down bombs, to withstand extremely high accelerations and decelerations. The latter features could affect the operation of a nuclear warhead and could be the source of uncertainty in the event of a stockpile aging problem.

Conclusions

Nuclear weapons research and development, supported by nuclear testing, is essential to maintaining the credibility of the U.S. nuclear deterrent. Because the global strategic balance is constantly changing, new weapon systems must be developed to ensure the safety, security, survivability, and military effectiveness of the deterrent. The DOE weapons design laboratories have the dual responsibility of ensuring that the weapons currently in the stockpile are safe and reliable and of developing warheads for new systems as they are needed.

Nuclear testing is essential if the laboratories are to meet this responsibility successfully. Nonnuclear tests and computer simulations are very valuable tools, but there is no substitute for the experimental data from nuclear tests. In many instances, weapons scientists must rely on technical judgment to make decisions regarding problems that arise in the stockpile, in recommending changes in weapon systems, and in developing new warheads—judgment that can only derive from and be refined with actual data from nuclear tests. The importance of nuclear testing was illustrated by our experiences with the test moratorium of 1958-1961. Without nuclear testing, deterrence would still be based on nuclear weapons but at significantly higher cost and with greater uncertainty.

Key Words: Comprehensive Test Ban (CTB); earth-penetrating warhead (EPW); ground-launched cruise missile (GLCM); high explosive—conventional, insensitive, TATB; laser—Nova; nuclear directed-energy weapon (NDEW); nuclear weapon—design, research and development, stockpile aging, testing; small intercontinental ballistic missile (SICBM); Strategic Defense Initiative (SDI).

Notes and References

1. The May 1983 and August 1986 issues of *Energy and Technology Review* (UCRL-52000-83-5 and UCRL-52000-86-8) describe many of the Laboratory's efforts in treaty verification and arms control.

SAFEGUARDS

Now and for the foreseeable future, our nuclear weapons stockpile plays a prominent role in our national security posture. As long as this is the case, we must safeguard the efficacy of that stockpile and our confidence in it. These safeguards are considered an essential element in ensuring the nation's ability to have the technical means and knowledge necessary to support the nuclear deterrent and existing and future national security policy.

Safeguard "A":

- The conduct, within the constraints of existing treaties on nuclear testing, of comprehensive, aggressive, and continuing underground nuclear test programs designed to add to our knowledge and improve our weapons in all areas of significance to our military posture for the future.*

Safeguard "B":

- The maintenance of modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology which will attract, retain, and ensure the continued application of our human scientific resources to those programs on which continued progress in nuclear technology depends.

Safeguard "C":

- The maintenance of the basic capability to resume essential nuclear test programs, in prohibited environments; and to conduct testing promptly in prohibited yield ranges, should such tests be deemed essential to our national security.

* For the purpose of Safeguard "A," the underground nuclear test programs shall include, but not be limited to, tests sufficient to insure that our nuclear forces and their supporting command, communications and intelligence systems are safe, secure, effective, reliable and survivable, and to advance our understanding of nuclear-weapon effects.

Safeguard "D":

- In conjunction with a vigorous verification program, the conduct of a comprehensive, and continuing research and development program to improve our monitoring capabilities and operations with a goal of providing high confidence monitoring of those actions from which non-compliance with existing nuclear testing treaties could be inferred.

Safeguard "E":

- The continuing development of a broad range of intelligence gathering and analytical capabilities and operations to improve our knowledge of the nuclear arsenals, nuclear weapons development programs, related nuclear programs, and the capabilities and achievements of the Soviet Union and other nations.

Safeguard "F":

- The conduct of a governmental review at periodic intervals to determine whether continued compliance with the provisions of existing treaties on nuclear testing is in the US national security interests.

News Release

KRON TV 1001 VAN NESS AVENUE SAN FRANCISCO CA 94109 (415) 441-4444

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Hold for release until Friday, May 9 at noon (PDT)

KRON-TV EXCLUSIVE: DO SOVIETS CHEAT ON NUCLEAR TESTS?
PENTAGON SCIENTISTS SAY TOP REAGAN OFFICIAL REJECTS THEIR EVIDENCE

(San Francisco) -- KRON-TV will report tonight that the Pentagon's top arms control official has rejected repeated findings by Pentagon scientists who say the Soviet Union has not, as the Reagan administration claims, cheated on its 1974 test ban treaty with the United States.

The controversy between Assistant Secretary of Defense Richard Perle and the scientists will be reported by KRON's political specialist Rollin Post and investigative producer Brian McTique. The segment pits Perle against earthquake experts hired by the Pentagon to monitor underground Soviet testing.

One expert, Dr. Lynn Sykes of New York's Columbia University, told KRON, "The treaty itself, it states that neither country shall test above 150 kilotons, and I have no evidence that indicates the Soviets have done that." In fact, Post reports agreement among earth scientists that the treaty almost certainly has been honored by both parties.

KRON reveals that Perle attempted last year to steer the conclusions of intelligence estimates on the issue, evidenced in an April 15, 1985 letter to Gen. James Pfautz, former Air Force Assistant Chief of Staff for Intelligence, who had turned to seismologists for advice on the Soviet testing issue.

According to two sources who have seen the letter, Perle warned the general that the intelligence community, including military intelligence, was undermining the administration's position on Soviet cheating. Perle added that his own department would retain control of interpreting the evidence.

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"If the scientific data doesn't quite agree with your political position, what is done is to bend the data a little bit," said Dr. Charles Archambeau, a University of Colorado scientist who has worked for the government on the Soviet testing issue since the Eisenhower administration.

"Baloney," replied Perle. "It's a question of scientists playing politics...They are all a bunch of seismologists, feathering their own nests. The day we can get along without attributing the importance to seismology that we do, some of these fellows will be looking for jobs."

Last year, Perle had the Defense Intelligence Agency convene a special panel of scientists to weigh all the kinds of intelligence--seismic and non-seismic--that the United States uses to assess the size of Soviet nuclear tests.

"They came to the conclusion that of the many ways of estimating yield, seismology was the single most important, and I happen to agree with that," Perle tells Post in the KRON report. That panel, like two other, similar, ones recommended interpreting intelligence data to suggest that the Soviets have abided by the treaty.

"The best experts available spent years studying this and came to the conclusion it is likely the Soviets have violated the 150 kilotons," Perle told Post in an interview last week at the Pentagon.

"I don't believe that the evidence supports a militarily significant violation," said Dr. Willard Hannon, chief of seismic monitoring for Lawrence Livermore National Laboratory near San Francisco. (Hannon emphasized he spoke as an individual scientist, not for the laboratory.)

Perle failed to name to KRON a single seismologist who agrees with his assertion of test ban cheating, or where his "best experts" reached their conclusion. The Assistant Secretary of Defense cites satellite and electronic surveillance, among other intelligence product, as the basis for his belief, but the earth scientists interviewed by KRON say that the increased sensitivity of monitoring equipment makes test yield estimates especially reliable.

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"The scientific opinion is, I'd say, close to unanimous," Professor Archambeau told KRON. "Right now, Mr. Perle finds it extremely difficult to find any scientist that will defend the D.O.D.-Perle position, and that's because there aren't any who will believe it."

Columbia University's Sykes, who helped negotiate the treaty itself during the Nixon administration, told KRON, "I think that one view is often put forth, and that is that arms control agreements are not in the best interests of the United States and the Soviets will cheat. And they attempt to have a self-fulfilling prophecy by coming up with some procedure, an incorrect one, that indicates to them the Soviets have cheated."

Continued nuclear testing is necessary to develop the Star Wars program.

The Target 4 Unit investigative report is scheduled for broadcast on KRON's "NewsCenter 4" at 6. KRON is an NBC affiliate, owned by Chronicle Broadcasting of San Francisco, Inc. Political specialist Post is the dean of KRON's reporting staff and producer McTigue was honored last month with a George Polk award in journalism for reports on worker health hazards in Silicon Valley electronics firms. Mike Ferring is KRON news director.

***

Principal figures in KRON's report:

Assistant Secretary of Defense Richard Perle (202) 695-0942

Seismologist Lynn Sykes, Columbia University (914) 359-2900 ext. 280

Seismologist Charles Archambeau, University of Colorado at Boulder (303) 492-8028.

Seismologist Willard Hannon (Lawrence Livermore National Laboratory) (415) 422-3921.

For transcripts of KRON's report, contact Jodie Chase at (415) 561-8658.

ARCHAMBEAU SOT: "If the scientfic data doesn't quite agree with your political position, what is done is to bend the data a little bit.

PERLE SOT: "Baloney, it's not a question of scientific evidence, it's a question of scientists playing politics."

TRACK: THE ARGUMENT CONCERNS UNDERGROUND TESTING OF NUCLEAR WEAPONS.IN 1974 THE UNITED STATES AND SOVIET UNION AGREED TO A TREATY THAT SAID EACH SIDE COULD TEST NUCLEAR WEAPONS AS LONG AS THE EXPLOSION DIDN'T EXCEED 150 KILOTONS, WHICH IS STILL 10 TIMES LARGER THAN THE HIROSHIMA BOMB.

PERLE SOT: I've looked carefully at the evidence and have concluded, as President Reagan did, that there is a significant evidence the Soviets have violated the 150 kilton threshold.

TRACK: This has been the position of the Administration since 1983. A position formed and spearheaded by Assistant Secretary of Defense Richard Perle.

But it also caused a rebellion amoung the very scientists the Defense Department relies on to estimate the size of the Soviet Tests.

So deep has been the controversy that last year the Defense Department secretly convened three groups of experts who monitor Soviet tests.

They are seismologists--the same people who measure the size of earthquakes.

Target 4 interviewed some of those seismologists and they all said the Soviet Union has not violated the 1974 Test Ban Treaty.

TRACK: ONE OF THEMM IS CR. CHARLES ARCHAMBEAU WHO HAS BEEN MONITORING THE SOVIETS SINCE THE EISENHOWER ADMINISTRATION.

ARCHAMBEAU SOT: "There is no evidence that the Soviets have tested over 150 kilotons. NONE WHATSOEVER

TRACK: ANOTHER IS PROFESSOR LYNN SYKES WHO NEGOTIATED THE TEST BAN TREATY FOR THE NIXON ADMINISTRATION.
SYKES SOT: "The treaty itself, it states that neither country shall test above 150 kilotons, and I have no evidence that indicates the soviets have done that."

TRACK: DR. WILLARD HANNON HEADS SEISMIC MONITORING FOR THE LAWENENCE LIVERMORE NATIONAL LABORATORY.
HAMMOND SOT: My information is that the Soviets have not tested over the treaty in a militarily significant way.

TRACK: THE MAN WHO ULTIMATELY RECIEVES THIS ADVISE IS REICHARD PERLE. HIS POSITION WAS FAR DIFFERENT.
PERLE SOT: "The best experts available spent years studying this and came to the conclusion it is likely the Soviets have violated the 150 kilotons."

POST: "There are seismologists who have written, for instance, Dr. Charles Archambeau, I think you know it, wrote that "There are at present no evidence that the Soviets have tested over 150 kilotons, none whatsoever"

PERLE: Well with all due respect, he is wrong there is lots of evidence, he may not be persuaded on the basis of the evidence, but to say there is no evidence is just flat wrong.

POST: Dr. Lynn Sykes of Columbia says the Soviet Union has not violated the 150 "kt" limit of the Threshold Treaty, as alleged," Is he wrong?

PERLE: He is entitled to his opinion, he is a Professor sitting up at Columbia,

POST: But he is an authority on the issue--

PERLE: Well, ah, all the seismologist can do is enable you to estimate the yield of an event. Even by that standard alone, there is evidence that suggests that the Soviets have violated it. Your experts not withstanding.

POST: They were your experts at one time. They worked for the Defense Department.

well, that ah,ah, is of a sensitive and classified nature.

TRACK: MR. PERLE WOULD ONLY SAY THE OTHER EVIDENCE INVOLVED SATELLITE AND ELECTRONIC SURVEILLANCE. BUT TARGET FOUR'S INVESTIGATION LEARNED THAT MR. PERLE HAD ALREADY CONVENED A PANEL OF EXPERTS WHICH LOOKED AT THIS "OTHER EVIDENCE" AND REJECTED IT.
POST: "Well you had a Defense Intelligence Agency study not very long ago for precisely that--to evaluate various siesmic and non-seismic ways of determining what Soviets are doing and they still come up with the conclusion that seismology was the most accurate way."

PERLE: "They came to the conclusion that of the many ways of estimating yield, sesimology was the single most important and I happen to agree with that."

TRACK; EVEN AFTER ACKNOWLEDGING SEISMOLOGY IS THE BEST INDICATOR, MR. PERLE REJECTS IT.

PERLE SOT: I didn't particualrly care much what the answer was. It doesn't have any profound bearing on our policy.

TRACK: TARGET 4'S INVESTIGATION HAS ALSO UNCOVERED EVIDENCE THAT MR. PERLE IMPROPERLY TRIED TO MANIPULATE INTELLIGENCE AGENCIES IN A BIASED DIRECTION.

EXAMPLE: A PERLE LETTER TO THE AIR FORCE WHEN ITS INTELLIGENCE UNIT ASKED SEISMOLOGISTS TO ADVISE ON SOVIET NUCLEAR TESTS.

ACCORDING TO SOURCES WHO HAVE SEEN THE LETTER, IT SAID:

THE INTELLIGENCE COMMUNITY IS UNDERMINING THE ADMINISTRATION'S POSITION.

MY DEPARTMENT WILL CONTROL THIS AREA

I ASKED PERLE ABOUT THE LETTER.

POST: "There was a letter I understand that you wrote on April 15th of last year to general PFATZ who's the Air Force Assistant Chief of Staff for Intelligence.

POST: Used to be...

PERLE: I don't remember the exact words of the letter, but my concern was the concern that I've been trying to express throughout this interview, which is that we have tended, I think wrongly, to exclude the non-seismic evidence.

STAND-UP: WHEN YOU CUT THROUGH THESE DISAGREEMENTS, YOU FIND THAT THE REAL ISSUE MAY BE MORE PERSONAL AND POLITICAL THAN SCIENTIFIC.

PERLE: "They are all a bunch of seismologists, feathering their own nests.

Look, the seismologists have dominated this field from the beginning and that's how they make a living. The day we can get along without attributing the importance to seismology that we do, some of these fellows will be looking for jobs."

ARCHAMBEAU: The scientific opinion is, I'd say, close to unanimous ((butt)) Right now Mr. Perle finds it extremely difficult to find any scientist that will defend the DOD-Perle position--and that's because there aren't any who will believe it."

SYKES: "I think the one view that is often put forth, and that is that arms control agreements are not in the best interest of the United States, and the Soviets will cheat. And they attempt to have a self-fulfilling prophecy by coming up with some procedure, an incorrect one, that indicates to them the Soviets have cheated."

THE NEW YORK TIMES, WEDNESDAY, APRIL 2, 1986

C.I.A. CHANGES WAY THAT IT MEASURES SOVIET ATOM TESTS

MAY AFFECT ARMS STANCE

Lower Estimates of Yields — Officials Debate Issue of Past Russian Cheating

By MICHAEL R. GORDON

Special to The New York Times

WASHINGTON, April 1 — The Central Intelligence Agency has changed its procedures for estimating the yield of large Soviet nuclear tests because it has decided its previous estimates were too high, Reagan Administration officials said today.

The officials said the decision to use the new method was made in January by William J. Casey, the Director of Central Intelligence, despite objections by some Defense Department officials.

The C.I.A. decision has raised questions about past Administration assertions that the Soviet Union had probably violated the Threshold Test Ban Treaty of 1974, which limits underground tests to no more than 150 kilotons.

Reagan Requests a Report

Before the C.I.A. decision was made, President Reagan ordered a report on how the change would affect Administration concerns about Soviet violations, the Administration officials said. That report has not yet been completed.

Mr. Casey formally approved the change on Jan. 21, officials said. Experts familiar with the change said it would lower estimates of the yield of Soviet tests by about 20 percent.

Richard N. Perle, the Assistant Secretary of Defense for International Security Policy, reportedly opposed adopting the recommendations and argued that the issue needed more study. Mr. Perle declined to discuss the issue.

Edward P. Djerejian, a White House spokesman, said the White House had no comment at this time on the decision or its implications.

Administration experts, who asked

C.I.A. Changing Procedures Used to Measure Soviet Nuclear Tests

Continued From Page A1

not to be identified, were divided about whether the change should lead the Administration to drop its allegations against the Soviet Union.

The accusations of Soviet arms control violations have become a central issue in United States-Soviet relations. No significant progress has been made in this area since the November summit meeting of President Reagan and Mikhail S. Gorbachev, the Soviet leader.

Deliberations Over Treaty

The Reagan Administration is deliberating what actions to take in response to reported arms control violations and whether to modify its commitment not to undercut the 1979 Strategic Arms Limitation Treaty.

The Administration has said that many of the Soviet tests had "likely" violated the threshold treaty, which stipulates that the size of warheads being tested should not exceed 150 kilotons, equal to the explosive force of 150,000 tons of TNT. The Soviet Union has denied violating the treaty.

Administration and nongovernmental experts have long questioned the accuracy of the intelligence estimates on which the charges were based.

The debate has centered on the seismological procedures for assessing the yield of nuclear tests. The main Soviet test site at Semipalatinsk in Central Asia is geologically different than the site in Nevada where the United States conducts its tests.

Scientists say that because of this Soviet explosions produce a larger seismic wave than American tests of the same size.

American intelligence estimates of Soviet tests have long been adjusted for the difference, but many experts said the adjustment factor was too small.

Officials said the question of changing the American procedure had been under study for years.

New Studies Come to Light

The issue came to the fore again last year after several new studies.

On Oct. 18, a panel of scientists selected by the Defense Advanced Research Projects Agency prepared a classified report that concluded the Government's method for estimating the yield of Soviet explosions was based on faulty assumptions.

The eight-member panel recommended a change in procedures that would lower the estimates.

The panel's report was submitted in late October to the Joint Atomic Energy Intelligence Committee, which issues reports on the size of foreign nuclear explosions. The committee is made up of members from the military services and intelligence agencies.

Second Study Adds Support

Adding support to the scientists' recommendation was a separate study, also completed in October, that was overseen by the Air Force Technical Applications Center, which operates a system of seismic stations to monitor Soviet tests. This study agreed with the finding of the military research agency report.

On Dec. 17, the Joint Atomic Energy Intelligence Committee recommended that the C.I.A. adopt the advice in the report commissioned by the research agency. Officials said the Defense Intelligence Agency disagreed, but was overruled.

The new C.I.A. procedure will be used to estimate the size of explosions in the Shagan River area near the city of Semipalatinsk, where the Soviet Union conducts its largest nuclear tests. Officials said they expected the new estimating procedure to be applied to the next Soviet test in this area. The Soviet Union has not held a nuclear test since last summer, when it declared a unilateral moratorium on tests and asked the United States to join in a total test ban. The Reagan Administration has refused.

Reagan Signs Directive

At the time the Administration prepared its report to Congress charging Soviet arms control violations, President Reagan signed a National Security Decision Directive, NSDD 202, that asked for a report on how the new method would reflect on past United States charges of violations by the Soviet Union.

This is the report that has not been completed, and officials are divided about whether enough evidence now exists to say the Russians have been violating the treaty.

Officials said applying the new method retroactively would still leave about a dozen Soviet tests that appear to be above the limit, and one official said only three or four of these exceeded the limit enough to warrant special concern.

The new procedure also suggests that the largest Soviet blast since the signing of the threshold treaty in 1974 was no higher than 250 kilotons. The Administration has previously said that the Soviet Union has conducted a test that was greater than 300 kilotons.

Violations Still 'Likely'

One Administration official said the new data still point "in the direction of a likely violation" and noted that the Administration qualified its charges against the Soviet Union.

But another official said the change in the estimating procedure would significantly undercut the charges.

He said that given the uncertainty involved in seismic measurements, some Soviet tests would be expected to register above the 150-kiloton limit. He added that some American tests that were under that limit might also appear to the Soviets to exceed it.

A spokesman for the Arms Control and Disarmament Agency said the agency was "not in a position to put forward any official agency view on this matter at this time."

Some Longstanding Questions

While officials familiar with the C.I.A. decision declined to be quoted on the record, other experts have openly supported the view that some estimates of the yield of Soviet tests have been too high.

Roger Batzel, the director of the Lawrence Livermore National Laboratory, in California, said in written testimony to Congress yet to made public that the Soviet Union might be complying with the treaty.

"Based on our assessment of the relationship between yield and seismic magnitude for the Soviet test site and the pattern of Soviet testing," he said, "We have concluded that the Soviets appear to be observing a yield limit. Our best estimate of this yield limit is consistent" with the threshold test ban. "However," he added, "the seismic data are subject to considerable statistical uncertainty."

That view differs from officials at the Los Alamos National Laboratory, in New Mexico, who have told Congress that verification of the threshold treaty is highly uncertain.

But a retired admiral, Sylvester R. Foley Jr., the Assistant Secretary for Defense Programs at the Energy Department, which oversees nuclear testing, said in an interview that he tended to agree with Mr. Batzel's assessment.

"You can make that statement when you throw hedges in," he said. "When you aggregate all of these together, there were some violations yes, but perhaps not as many as originally indicated. And the range of these explosions, certainly, in recent times probably falls within the threshold test ban."

UCID-20804

EVALUATION OF THE 1983 ROSENGREN REPORT FROM THE STANDPOINT OF A COMPREHENSIVE TEST BAN (CTB)

Ray E. Kidder

June 17, 1986

Lawrence
Livermore
National
Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

EVALUATION OF THE 1983 ROSENGREN REPORT*
FROM THE STANDPOINT OF
A COMPREHENSIVE TEST BAN (CTB)

Ray E. Kidder

June 17, 1986

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* Some Little-Publicized Difficulties with a Nuclear Freeze, Jack W. Rosengren, R&D Associates, 4640 Admiralty Way, Marina Del Rey, CA 90291, Report RDA-TR-122116-001, October 1983.

I. INTRODUCTION

Over the past several months, Administration officials have frequently cited an unclassified 1983 study by a Department of Energy contractor to substantiate arguments that a Comprehensive Test Ban Treaty would degrade the reliability of the U.S. Nuclear deterrent. The study, by Jack W. Rosengren of R&D Associates, is titled "Some Little-Publicized Difficulties with a Nuclear Freeze." It argues that judging from past experiences, a ban on the underground testing of nuclear weapons could be expected to severely undercut the capability of the U.S. to maintain a reliable nuclear weapons stockpile. This study has been submitted into the record of at least three Congressional hearings on the test ban, and was the subject of a front page article in the Washington Post.

In support of the thesis that a ban on nuclear weapons tests would severely undercut our capability to maintain a reliable stockpile, Rosengren cites difficulties experienced with one tactical nuclear weapon and five nuclear warheads after they were placed in stockpile. They are:

The W45 tactical nuclear weapon
The W47 first Polaris missile warhead
The W52 Sergeant missile warhead
The W56 Minuteman missile warhead
The W58 second Polaris missile warhead
The W68 first Poseidon missile warhead

The question we address in this evaluation is: Do the examples cited in the Rosengren Report support the thesis that nuclear explosive testing is necessary to maintain confidence in the reliability of the existing U.S. nuclear stockpile of thoroughly tested nuclear weapons?

It is our conclusion that none of the examples presented support such a thesis.

II. DISCUSSION OF THE SIX EXAMPLES CITED

Of the six nuclear weapons cited as examples, four were developed, at least in part, during the 1958-1961 moratorium on nuclear testing. The existence of this 3-year hiatus in testing, together with a desire to make up for lost time, led the design Laboratories to certify these weapons for stockpile before they had been adequately tested, as later experience was to prove. Confirmation that these weapons were inadequately tested is provided by the Rosengren Report itself. About the W45, Rosengren states:(1)

> "Early in the career of the W45, LLNL tested it under circumstances that were similar to those of an earlier test but with certain small changes *that (were known to) occur with aging in stockpile*. The result was a rude surprise: The test device gave only about half its rated yield." (Page 23)

The "certain small changes" referred to were the result of radioactive decay, a known effect of aging that can be easily and accurately simulated. The W45 had been certified for stockpile before its sensitivity to this known effect had been properly evaluated in a nuclear test.

The W47 was similarly characterized as having been inadequately tested before being stockpiled:

> "The weapon was put into stockpile during the nuclear-test moratorium of 1958-1961 *without having had enough tests* to fully resolve certain design problems." (Page 14)

About the W52:

> "The Laboratory staff made this decision (to change the high explosive system) during the nuclear-test moratorium 1958-1961, when they could not test the *new design* in a nuclear event." (Page 24)

That is, the *new design* of the W52 had been certified for stockpile without *any* nuclear tests.

About the W56:

> "LLNL developed the W56 warhead for the Minuteman MK 11 reentry vehicle in large part during the 1958-1961 test moratorium, when the Laboratory *could not test the device*.

---

(1) Emphasis and words in parentheses have been added to the quotations presented.

> For certain reasons related to the inability to test, LLNL provided a mechanical arming arrangement as part of the basic nuclear structure."
>
> "In a reasonably short time the weapons engineers were able to arrive at an acceptable redesign (of the arming mechanism), one that had so little change that it did not require evaluation in a nuclear test." (Page 21)

That is, no nuclear test was required to correct the problem; and the problem would not have arisen in the first place had not the moratorium interfered with necessary nuclear tests.

The remaining two warheads cited, the W58 and the W68, encountered problems unrelated to the test moratorium. In the case of the W58, the problem was resolved without requiring a nuclear test:

> "The AEC (later ERDA) and the Navy were able to counter these (corrosion) problems by certain minor changes to the warheads at Navy maintenance facilities, without any further nuclear tests being required or any major rebuilding." (Page 18)

In the case of the W68, a complete rebuild of all weapons in stockpile was undertaken in which the high explosive (LX-09), which was found to produce a harmful chemically reactive effluent, was replaced with another explosive (LX-10) which did not. With respect to this modification, Rosengren states:

> "On the basis of the earlier nuclear tests, LLNL was confident of the reliability of the modified warheads, and the (certifying) Laboratory did not require a new nuclear test. However, as a "final development test," LLNL did test the W68 again after the retrofit. In this test, LLNL used a weapon that was in many ways at the edge of acceptable tolerances and had one limited-life component with an age that was over that of any to be used in the stockpile. This extreme test device performed successfully, confirming the Laboratory's confidence." (Page 20)

A summary of nuclear-test actions taken, and results obtained with the six nuclear weapons cited in the Rosengren Report is provided in Table I.

TABLE I: Nuclear-Test Actions Taken After Stockpile Certification of the Six Nuclear Weapons Cited in the Rosengren Report

Weapon Designation	Nuclear Test Performed?		
	No. Not Believed Necessary	Yes Device Performance?	
		Satisfactory	Unsatisfactory
W45(1)			X
W47(1)		X	
W52(1,2)			X
W56(1)	X		
W58	X		
W68(2)		X	

(1) Inadequately tested prior to stockpile entry, as a result of the 1958-1961 nuclear-test moratorium.

(2) Test necessitated by one or more substantial design changes that could seriously influence nuclear performance. (High explosive replaced by a different high explosive).

III. SUMMARY AND CONCLUSIONS

We conclude that none of the examples cited in the Rosengren Report support the thesis that nuclear explosive testing is necessary to maintain confidence in the reliability of the existing U.S. nuclear stockpile of thoroughly tested nuclear weapons for the following reasons:

No nuclear tests were required either to identify or to correct the problems encountered in stockpile with the W56, W58 and W68. None were performed with the W56 or W58. A successful "final development" test of the W68 was conducted which the Laboratory responsible for certification of the warhead did not require.

The W45, W47, and W52 were not adequately tested prior to stockpile entry in the early sixties, largely as a result of the 1958-1961 nuclear test moratorium.

January 8, 1987

Professor Frederick Reines
Dept. of Physics
University of California
Irvine, CA 92717

Dear Professor Reines:

In accordance with your telephone request of December 12 I have prepared a short report (classified, SRD) entitled Evaluation of Recent Problems with the U.S. Stockpile of Nuclear Weapons from the Standpoint of a Comprehensive Test Ban (CTB). This report reviews the Classified Addendum of Roger Batzel submitted into the record of the hearing before the Special Panel on Arms Control and Disarmament of the Procurement and Nuclear Systems Subcommittee of the House Armed Services Committee on September 18, 1985. It is intended to supplement and bring up to date my earlier unclassified report entitled Evaluation of the 1983 Rosengren Report from the Standpoint of a Comprehensive Test Ban (CTB), UCID-20804, June 17, 1986 (copy enclosed).

Dr. Batzel's Classified Addendum describes problems encountered in the stockpile with the W68 Poseidon missile warhead and, more recently, with the W80 air-launched cruise missile warhead, and the W84 ground-launched cruise missile warhead. A copy of my classified review of this document will be forwarded to you under separate cover.

I have concluded that none of the six examples cited in the unclassified Rosengren Report, namely the W45, W47, W52, W56, W58, and W68; nor any of the three examples cited in Dr. Batzel's Classified Addendum, namely the W68, W80, and W84; support the thesis:

> That nuclear explosive testing is necessary to maintain confidence in the reliability of the existing stockpile of thoroughly tested nuclear weapons.

The basis for this conclusion with reference to the W45 through W68 may be found in the enclosed copy of UCID-20804. The basis with reference to the W80 and W84 is provided in my review of Dr. Batzel's Classified Addendum.

The difficulties experienced in stockpile with the W45, W47, W52, W80, and W84 were, in my view, the result of inadequate nuclear testing prior to being certified for stockpile. The 1958-1961 nuclear test moratorium was largely to blame for the lack of adequate testing of the W45, W47, W52, and W56. No nuclear tests were required either to identify or to correct the problems encountered in stockpile in the case of the W56, W58, and W68.

I hope that my evaluation of these stockpile difficulties will be of use to you. If you have further questions I will be glad to try to answer them.

Sincerely,

Ray E. Kidder
Theoretical Group
Physics Department

xc: Roger Batzel

Seismic Monitoring of Nuclear Explosions

Paul G. Richards, Department of Geological Sciences, Columbia University,
and Lamont-Doherty Geological Observatory, Palisades, NY 10964.

Introduction

Until 1957 all nuclear explosions were conducted near or above the surface of the Earth. But in that year, on September 19 in Nevada, the first underground nuclear explosion occurred. Code-named RAINIER, it was planned in part to see if nuclear testing could be done in an environment that was unhampered by the weather or by concerns over radioactive fallout, but still fulfilled all the needs of the test program. The resulting seismic data were studied intensively in both scientific and political arenas, setting a pattern that has continued ever since.

Over the last thirty years a special branch of seismology has developed associated with the monitoring of such explosions, most of which are weapons tests. As shown in Figure 1, there have been hundreds of underground explosions, conducted (so far) by six countries.

As the first nuclear explosion in which the radioactive products were "contained" in the vicinity of the shot point, RAINIER presented a technical challenge to those who, for whatever reason, wished to obtain details of such testing activity. The importance of this challenge has had a major impact upon the development of geophysics. In particular, seismology grew rapidly as a science in the 1960's in response to the need to monitor explosions, in part because of the need to monitor any nuclear test-ban treaty that might be contemplated between the U.S., the U.S.S.R., and other countries. For example, the first global network of calibrated seismographs as well as several large-aperture arrays were set up to improve the capability of seismology as a whole, with funding derived from the need for improved explosion monitoring. With openly available data from this instrumentation, great improvements globally in earthquake location accuracy were achieved; studies of earthquake focal mechanisms became practical; and detailed features of deep Earth structure were discovered.

In general the problems of monitoring nuclear testing are more severe for tests conducted underground, than for tests in space, in the atmosphere, or underwater. In 1963 these problems appeared to many to be insuperable, a fact which contributed to the form of the Limited Test Ban Treaty, signed and ratified in that year, and banning signatories from nuclear testing in all environments except underground.

The detection of explosions, and their discrimination from earthquakes, is easier for events of larger size. This fact influenced negotiation of the Threshold Test Ban Treaty in 1974, intended to take effect after March 1976, and prohibiting any underground nuclear weapons test having a yield exceeding 150 kilotons. (A kiloton, or kt, is an energy unit originally associated with the chemical energy of a thousand-ton TNT explosion; but it is now defined as 10^{12} calories. RAINIER, the first underground nuclear explosion, had a yield of 1.7 kt. The Hiroshima bomb was about 14 kt. Prior to negotiation of the 150 kt threshold, some underground tests had exceeded 1000 kt.) This Threshold Treaty introduced a third technical challenge to monitoring programs, beyond detection and discrimination, namely the question of yield estimation; and whether this can be done accurately by seismic means.

In 1974 the U.S.S.R. had ambitious plans to use nuclear explosions for re-directing major rivers from northerly to southerly flow, and for other civil engineering purposes. However, after 18 months of intensive negotiation it proved possible also to negotiate the Peaceful Nuclear Explosions Treaty of 1976, which extends the threshold of 150 kt on weapons test explosions to so-called Peaceful Nuclear Explosions (PNE's). In addition this Treaty permits PNE salvos with yield totals up to 1500 kt provided no individual explosion exceeds 150 kt. Although both the U.S. and the U.S.S.R. have declared their intention not to exceed the 150 kt threshold, there have been press reports that each country has raised questions as to whether the other side is indeed complying.

This brief history will indicate that technical capability to monitor explosions, or lack of such capability, plays a role in the development of policy options on weapons testing and/or arms control and the content of international treaties. The question of a Comprehensive Test Ban Treaty has been debated for thirty years, the fundamental issue being whether or not to assist continued advances in nuclear weapons technology. It is also clear that related to that debate are the technical issues of what size explosions, conducted underground, can be detected, discriminated from non-nuclear events, and accurately measured. Thus, if it is ever deemed in the national interest of the superpowers to negotiate a ban on future testing more stringent than Treaties now in effect, a key technical question will be: down to what value of yield can monitoring be accomplished? In this connection, much improvement in monitoring capabilities has been made since the 150 kt threshold came into effect in 1976. Some seismologists claim now that there is no fundamental technical problem with monitoring explosions down to 1 kiloton, even if determined efforts at evasion must be considered. Some are more cautious, claiming that the U.S. (even with access to sophisticated seismic data gathered within the U.S.S.R.) could monitor only down to about three times the size of RAINIER (i.e. down to about 5 kt). And some have asserted that it is possible to build cavities underground and use them to muffle and thus hide the seismic signal from a 30 kt explosion or even up to 100 kt. These latter assertions do not appear able to survive after review of the technical difficulties; but in fact, as assertions, one finds that they do continue to survive.

As Dr. Roger Hagengruber of the Sandia National Laboratory has noted: "The data provided by monitoring is viewed through a political lens." This fact was apparent at the very beginning of the underground test program, when pre-shot details for RAINIER were made available by the U.S. Atomic Energy Commission so that geophysicists could plan to pick up the resulting seismic signals and use them, for example, for the study of deep Earth structure. Whereas some scientists at an international scientific convention in 1957 were led by Professor Keith Bullen of Australia to organize a telegram of thanks to the AEC for releasing these details, the Soviet delegation walked out of the meeting.

Sections below make minimal reference to these political perspectives. Topics covered include basic properties of explosion signals as compared to earthquake signals; a description of the capabilities of certain global networks and of one array in particular; seismic estimation of explosion yield; and a review of some technical issues raised by methods that have been proposed as offering possibilities of treaty evasion.

Basic Properties of Explosion and Earthquake Signals

An underground explosion is a source principally of compressional waves having longitudinal motions, i.e. *P*-waves, because the explosion products apply a fairly uniform pressure to the walls of the cavity created by the explosion. However, transverse motions indicating shearing, i.e. *S*-waves, can occasionally be observed, due presumably to slight asymmetries of cavity loading, or to structural heterogeneities or the presence of initial shearing stresses near the shot point. An earthquake, on the other hand, is generated typically as a result of massive rock failure in a shearing mode, in which it is common to think in terms of two blocks of material (within the crust, for shallow events) on opposite sides of a fault. The earthquake is the outcome of a spontaneous process of stress release, during which the two blocks move rapidly with respect to each other, sliding in frictional contact on the plane of the fault. Because of this shearing motion an earthquake radiates predominantly transverse motions, i.e. *S*-waves. *P*-waves from an earthquake are generated at a substantial fraction of the *S*-wave level, but they are associated with a four-lobed radiation pattern of alternating compressions and rarefactions in the radiated first motions, rather than the relatively uniform pattern of *P*-wave compressions radiated in all directions out from an explosion source. These radiation patterns, *P*- and *S*-waves from an earthquake and *P*-waves from an explosion, are shown schematically at the top of Figure 2.

In addition to each type of body wave, each type of seismic source also generates seismic surface waves. For an explosion, the largest surface waves are usually of Rayleigh type, with a radiation pattern that usually varies little with azimuth. These features are presumed to be due to azimuthal symmetry of applied pressure on the cavity walls, and because (at most test sites) the lateral variations of Earth structure are insufficient to couple *P* - *SV* energy into Love waves (the other principal category of surface waves). When significant Love waves are observed from an explosion, as does occasionally occur, this is presumed to result from some release (triggered by the explosion) of tectonic stresses present in the vicinity of the shot point. Earthquakes, on the other hand, being entirely a result of tectonic stress release, generate both Rayleigh and Love waves, each with a radiation pattern which varies azimuthally and which can be expressed trigonometrically in terms of the spatial orientation of the underlying fault and the direction of relative block motions across that fault. The picture that emerges is usually one of relatively simple surface waves from an explosion as compared to those from an earthquake; however, some explosion signals are complicated by the superposition of an earthquake-like component in the radiation pattern. A further characteristic of surface waves for the two types of source is that, for shallow earthquakes and explosions generating about the same level of body wave signals, earthquakes are far more efficient generators of surface waves. This feature can be seen in the lower panel of Figure 2, and is the basis of a routine method for discrimination between the two kinds of seismic event.

In practice, for different seismic events there is great variability in the number of points on the radiation pattern that are sampled. Thus, for an event of interest it is important to know from how many directions around the source and at what distances there is available seismic data. There are thousands of seismographs operated around the world by hundreds of different institutions in tens of different countries. For most seismic events, only a cursory glance at the data from a few stations is required for the trained analyst to conclude immediately that a particular event is an explosion or an earthquake. However, this does not address the real problems of monitoring, which often concern a small number of events that are relatively difficult to interpret. Thus, a good monitoring program must meet some kind of requirement that all types of earthquakes and explosions above a certain size are detected with high probability; are located accurately; are correctly identified as earthquake or explosion; and are measured adequately (i.e. the yield of explosions must be estimated to a certain standard of accuracy, that standard being set by considerations outside of seismology).

Seismologists characterize the size of seismic signals by means of logarithmic magnitude scales, with each scale based on a different type of seismic wave. A magnitude scale using teleseismic surface waves was first described about 50 years ago, based on the logarithm (to the base 10) of amplitude of maximum ground displacement due to surface waves with periods about 20 s. It is known as the M_s scale. (The word "teleseismic" refers to observations at a distance of more than about 2000 km from a seismic source.) Another widely used magnitude scale is that based on the amplitude of teleseismic *P*-waves. Known as m_b, it entails measurement of ground motion at about 1 s period. As part of the assignation of M_s and m_b values, for a particular seismic event as recorded at a particular station, a standard correction is applied to account for the distance between the source and the receiver at which the data was obtained. Magnitudes range from about -3 for the smallest observable microearthquakes, up to above 8 for the largest earthquake. A one kiloton underground explosion has an m_b roughly about 4, and each year there are about 7500 shallow earthquakes worldwide with $m_b \geq 4$ (Ringdal, 1985). Note that magnitude is only an empirical estimator of seismic event size. Although use of seismic moment has superceded use of m_b and M_s in much of modern seismology, magnitude scales are still often used in discussion of seismic monitoring because this a practical way to relate that discussion directly to properties of signal strength.

Having run broadly through these relevant features of seismic signals, let us next pay attention to specifics of explosion monitoring. We shall describe detection capabilities of certain networks, and then briefly review the problems of discrimination and seismic yield estimation; and the special problems posed by potential evasion scenarios, in which attempts to hide an explosion are considered.

Detection

The Earth's surface continuously undergoes small motions, stimulated by ocean tides, winds, surf, and various activities of human society such as train and truck traffic, and pumping for oil. Seismic signals from earthquakes and explosions can be detected to the extent that they are stronger than this background noise, which varies greatly at different sites and in different frequency bands. Deployment of seismometers is more effective if sites can be found that are very quiet.

The signals of interest in seismic monitoring have a relatively impulsive nature. It follows that the detection of explosion signals can be done by comparing signal levels averaged over a short time (~ 2 seconds or less) with levels averaged over a longer period (~ 30 seconds), and continually updating the comparison. The analysis is traditionally done by eye, but it can be automated. Thus, a detector consists of one or more seismometers all in the same general location, plus some signal processor (human, or a computer).

With many different detectors, the next technical problem is recognizing an association between signals collected at different geographic locations: that is, of relating them to some presumed common source such as an earthquake or an explosion (whose signals have been picked up by a network deployed over some region of the Earth or perhaps over the whole globe); and of locating that source. The basic method of location is the same as that by which we use our two ears to tell from which direction a sound is coming. Our brain analyses the slight difference in the times at which a signal reaches our two ears. With a network of detectors of seismic signals, in effect each pair of detectors can be used to draw a line along which the source must lie. (The property of this line is that a source anywhere along it will generate the difference in signal arrival times actually seen at those two detectors.) With many such lines (one for each pair of detectors), the place where they all intersect must be the location of the source. For a good enough network and a strong enough source, the method has considerable redundancy. Signal detected at four or more stations, is usually enough to give a useful source location. A large underground explosion (150 kilotons) would be picked up at hundreds of seismometers around the world. A small explosion (1 kiloton) would be picked up on relatively few.

With many years of experience it has proven possible to assess the capabilities of a network of detectors, given the location and sensitivity of each seismometer and also a characterization of noise levels at each site in the network. A useful way to describe these capabilities, both actual and predicted, is by contouring the globe in magnitude units, that give the threshold value of source strength above which a seismic source will be detected with high probability and at enough stations to be located by the network. Figure 3 shows the actual and the predicted value of these contours, for a particular network of 115 globally distributed stations, requiring 90% probability of detection (for events near the threshold level) at at least four stations, at least one of which must be at a teleseismic distance (Ringdal, 1985). This is a quite stringent standard of detection capability. Though this was a "globally distributed" network, it suffered from relatively poor coverage in the southern hemisphere. Only a few useful stations could be found in Africa and South America. Thus, for this network, although the detection threshold has m_b in the range 3.9 - 4.3 in the northern hemisphere, the range is 4.2 - 4.8 in the south.

To improve detection capability for sources in some particular part of the world, one would need to add stations located at distances favorable for picking up signals from that region. Figure 4 shows how signal level drops with distance, and indicates the advantage of being able to use signals at so-called "regional distances" rather than relying on "teleseismic distances." This bears on the question of whether in-country stations are required, on the territory of a nation being monitored for purposes of treaty compliance; or whether compliance can be monitored from outside of that country. Regional signals can have characteristics quite different from those recorded teleseismically (e.g. different frequency content; greater sensitivity to local geology; possibility of propagation guided purely by crustal structure). Empirically it is found that when explosions of a few tons are detonated at shallow depths, regional signals can be picked up several hundred kilometers away even for propagation paths that (from geological and geophysical considerations) would be considered unfavorable. An example is shown in Figure 5.

The above discussion has described how individual seismological stations may contribute to detection capability, and some of the considerations that arise in evaluating a global network. Another practical element is introduced when one considers the capabilities of a group of seismometers in the same general region, all operated together as an "array," with central processing facilities that allow the multi-channel signals to be filtered, delayed, and summed. Figure 6 shows the location of the Norwegian Seismic Array (NORSAR), and a map view of the 3800 km.- long path to NORSAR from the main Soviet test site near the town of Semipalatinsk in East Kazakhstan, at about 50° N, 49° E. The lower part of the Figure displays the first 20 sec. of the *P*-wave arrivals at individual NORSAR sensors, from a Soviet nuclear explosion at this test site. Note that some sites appear more sensitive than others. For example, there are stronger signals at locations labelled 04C and 06C; and 05B and 07B are weaker than average. This illustrates an important property of seismic body wave amplitudes, namely their spatial variability, which here is presumably a result of focussing and defocussing within the crust and upper mantle.

Significant improvement in seismic signal-to-noise ratio can be achieved with a good array, as compared to this ratio for a single sensor. Thus, by adding the signals of Figure 6 (after an appropriate time shift to bring all the *P*-arrivals to a common reference time), the signal is enhanced if the *P*-wave first motion is coherent across the array; and the relatively incoherent noise (which is apparent prior to *P* on each sensor) is suppressed. The outcome of such processing is often referred to as the "beam" formed by the array, which may be "steered" to "look" at different source regions by using the set of delays at each sensor appropriate for each source region, prior to signal summation. An example of the NORSAR beam is shown in the upper part of Figure 7 for a Semipalatinsk explosion with m_b 4.5. Comparison of the signal strength with noise levels prior to the *P*-arrival indicates here that events with much lower m_b would be detectable. It is natural to explore the detection threshold for NORSAR, applied to Semipalatinsk explosions, by experimenting to find how much this m_b 4.5 signal can be scaled down before it is lost in the preceding noise. Equivalently, one can scale up the noise, leaving the signal level unchanged, and this is what is shown in Figure 7 (lower). It is found that the signal to noise amplitude ratio in the original seimogram is about 100 times greater than what is required for automatic detection by the array. In this example, which gives a particularly favorable result, the detection threshold is estimated as only m_b 2.45. Typical thresholds achieved from such scaling experiments, for this one array, are reported in the following table:

REGION	m_b range
West of Ural Mountains	2.0 - 2.5 (possibly better)
Caspian Area	2.0 - 2.5
Semipalatinsk	2.5 - 3.0
Siberia	2.5 - 3.5.

The favorable sensitivity of site 06C at NORSAR has already been noted. In June 1985, after some years of careful preparation, a small array known as NORESS (Norwegian Regional Array System) was formally declared operational at this location. It consists of 25 seismometer sites over an area about 3 km. across, linked by optical fiber to a central processing facilty. At the top of Figure 8 is shown a single sensor record, and the NORESS beam, for an Eastern Kazakh explosion with m_b 4.9 on July 25, 1985. The spectra of these records are shown in the lower part of the Figure, together with noise spectra. It is seen that even at this distance, nearly 4000 km from the source, there is significant signal above noise out to 15 Hz. The beam signal loss is negligible up to 6 Hz., and there is very good noise suppression in the beam around 2 Hz. (This latter property was a goal of the array design.) The remarkable detection capabilities of NORESS for teleseismic sources are further displayed in Figure 9, which is for a small (m_b 3.5, presumably sub-kiloton) explosion near Semipalatinsk on July 11, 1985.

NORESS was designed for signals from sources at "regional" distances, and the detection threshold for this array is down to about $m_b = 2.0 - 2.5$ at 1500 km. epicentral distance. At regional distances, the seismic waves *Pg*, *Pn*, *Sn* and *Lg* are commonly seen. (*Pg* propagates wholly within the crust; *Pn* and *Sn* travel in the top of the mantle, just below the Moho; and *Lg*, often the strongest signal, is guided largely by the crustal layer. See Figure 10.) Figure 11 shows NORESS spectra out to 20 Hz., for a presumed quarry blast near Leningrad, a little over 1000 km. away. *Lg* appears in a frequency band that differs from that of the *P*-wave, which is observed out to 18 Hz.

It has recently been shown for a single sensor that NORESS signals have important information in even higher frequency bands. Some important new results are shown in Figure 12. They use data from an advanced recording system that permits analysis of frequencies even above 50 Hz. Remarkably, for a magnitude 3.0 event 500 km. away, signal is about 20 dB above noise, all the way out to 50 Hz.

From this review of detection capability, it is apparent that the research frontier for seismic monitoring is represented by events roughly in the range $2 \leq m_b \leq 4$. Here, in contrast to large events, problems to be recognized include the much larger number of signals that must be processed, and the need to distinguish chemical explosions from nuclear explosions. Monitoring for a new test ban regime (for example, a low yield threshold) would likely cntail in-country networks of newly deployed seismometers in the U.S., the U.S.S.R. and elsewhere.

Discrimination

Seismic methods for discriminating between earthquakes and explosions are based on interpretation of the event location; on the relative excitation of a variety of body waves and surface waves; and on properties of the signal spectrum associated with each of these two different types of source. Within these three broad categories, many different methods have been tried, with various degrees of success, over the years since the RAINIER explosion of 1957. As the capabilities of each method are probed, the question of interest is often: "Down to what size of seismic event, does this method of discrimination work?" In some cases discrimination is unambiguous even at very small event size. (For example: however small an event, it may be presumed to be an earthquake if it is located at a depth greater than 15 km. below the Earth's surface. Another example: even a small event will *a priori* be regarded with high probability as an explosion, if it occurs in an area that is geologically stable, and that for decades has had no seismic activity.) But in general the threshold for discrimination is higher than that for detection, perhaps by around 0.5 m_b units (Hannon, 1985).

The most useful methods for discrimination can be listed as follows:

(1) Interpretation of the location. Is the event in a seismic or an aseismic area? Below the floor of an ocean? At depth below a continent?

(2) Relative amplitude of body waves and surface waves (see Figure 2). This can be studied by plotting the event of interest on an M_s: m_b diagram, such as the upper part of Figure 13. The surface-wave amplitude is read typically from signals with period about 20 sec., and the body-wave amplitude at about 1 sec. period.(Though effective for large enough events, an explosion with m_b much below 5 may not have large enough surface wave signals at teleseismic distances to apply this method dependably.)

(3) Use of radiation patterns (see upper part of Figure 2). Is the initial *P*-wave motion of the ground indicative of compression radiated to all directions from the source? Or, are dilatations recorded at some azimuths, indicating that the event has an "earthquake-like" radiation pattern? (This method has traditionally been applied to teleseisms, and is under study for regional signals.)

(4) Relative amplitude of body waves as recorded at high and at low frequencies. This method is being studied with frequencies in the range 0.5 - 50 Hz., to see if it can discriminate between very small earthquakes and explosions, even down to around m_b 2. The lower part of Figure 13 gives an example.

Fortunately, the cumulative effect of applying several methods can result in unambiguous separation of earthquakes and explosions, in situations where no single discriminant is successful. Thus, in a complete suite of about 1000 seismic events with $m_b > 4.5$ recorded on only nine stations, for a 162-day period in 1972, more than 90% could be identified as earthquakes because their depth was 30 km. or greater, and/or their epicenters were at sea by more than 25 km; the remainder were all identified as earthquakes by their observed M_s: m_b ratio (Sykes *et al.*, 1983). Incidentally, it appears that by the late 1960's - early 1970's, data available routinely to the international scientific community could be used for monitoring down to m_b 4.5 (Evernden, 1977).

Yield Estimation

For a few tens of underground nuclear explosions, most of them at the Nevada Test Site, the yield has been announced by the agency conducting the test. It has therefore been possible to calibrate observed seismic magnitudes for these tests against the announced yields, and an example is given in Figure 14 using m_b values and yields reported for Nevada explosions in hard rock. Such a calibration curve can be applied to obtain a seismic yield estimate for Nevada explosions with unannounced yield. But it requires correction, prior to its use in obtaining a seismic yield estimate for an explosion at a different site. This must be done, to allow for physical and geological differences between the sites. For example, in different rock types there can be different efficiencies in the coupling of nuclear yield into seismic energy; and differencies in the propagation efficiencies as seismic waves travel out from the source of interest, as compared to seismic signals from a Nevada explosion. In this connection, it is of interest to note m_b and yield for the U.S. nuclear explosion LONGSHOT (conducted in 1965 in the volcanic breccias of an Aleutian island). The m_b value is 5.9, corresponding to a yield of 300 kt. if the Nevada curve of Figure 14 is applied directly. But the announced yield for LONGSHOT is 80 kt. One way to obtain a calibration curve for the Aleutians is therefore to add a correction of about 0.4 m_b units to the Nevada values of m_b at a given yield, before the curve of Figure 14 is used to supply a seismic yield estimate in this new location. This m_b correction, for a site differing from that where a calibration curve is directly available, is called the bias. If the bias correction is not applied, then a Nevada calibration curve can give too high a seismic yield estimate for a non-Nevada explosion. Note that the Nevada Test Site is in a region of active tectonics, with significant episodes of volcanism in the last few million years, resulting in high temperatures within the upper mantle (and thus, anomalous attenuation of seismic waves propagating through the hot and partially molten upper layers of the Earth, 100 or 200 km in thickness beneath the Nevada Test Site).

The existence of m_b bias has long been known in seismology in connection with what is called "station bias". By this term is meant the systematic difference between mean m_b values (obtained for a particular seismic event by averaging reported m_b from seismometers all over the globe), and m_b reported by just one station. For example, years of experience tell that the station BMO in Oregon (another region of active tectonism) has reported m_b values that for a given earthquake are typically about 0.3 units below the global average; and station KJN in Finland (in a stable shield region) reports values about 0.15 m_b units higher than the average. Their station bias values are thus -0.3 and +0.15 respectively. Station bias values commonly range over ± 0.4 m_b units, and it may thus be expected that source region bias (which is what must be applied when a standard m_b - yield curve is used for different source regions) will also range over about 0.8 m_b units.

At sites for which little direct calibration data are available, several methods have been proposed with which to estimate the m_b - yield relation. These methods include: the use of surface waves; the study of differences in body-wave spectra at high frequencies; and comparison with known m_b bias at sites with similar geology. A lengthy review by Sykes and Ruggi (1987) gives the magnitude - yield relation for the main Soviet test site at Semipalatinsk as

$m_b = 4.262 + 0.973 \log_{10}(\text{Yield})$ for yields up to 75 kt., and
$m_b = 5.285 + 0.426 \log_{10}(\text{Yield})$ for yields above 75 kt.

Potential Methods for Evasion, and Conclusions

Several methods have been proposed, by which underground explosions could be concealed. One method is simply to make them small enough; but then there would be relatively little to learn, from the point of view of a weapons designer. The more important methods are those which combine as many features as possible, designed to reduce seismic signal-to-noise ratios at all relevant monitoring stations. Proposed methods include: emplacement of the nuclear device in material such as dry alluvium, to reduce the coupling of explosion energy into seismic signal; waiting until a sufficiently large natural earthquake occurs fairly near a test site, and then within a couple of minutes executing the weapons test so that its seismic signals would hopefully be swamped by the large and prolonged signals from the earthquake; and setting off a sequence of several explosions that are designed to simulate a natural earthquake signal. Careful study of each of these methods indicates that they are relatively ineffective in comparison with the method known as cavity decoupling, which we next discuss, and which is widely regarded as setting the practical levels down to which seismic monitoring of nuclear explosions is possible.

When an underground explosive device is tightly packed into its hole ("tamped" or "fully coupled"), and is detonated at sufficient depth to contain all radioactive products, a shock wave travels from the shot-point out into the surrounding rock some distance at speeds that exceed the normal *P*-wave speed. This non-linear phenomenon reduces at sufficient distance from the shot-point, and thereafter the wave propagation can be regarded as elastic. The so-called "elastic radius" for a tamped explosion, i.e. the radius beyond which wave propagation is linear, is roughly 100 meters times the cube root of the yield (in kilotons).

If, instead of being tamped the explosion is set off inside a large underground cavity, then the shock wave set up in the rock can be weakened. The explosion is said to be decoupled, and theoretical work begun in 1958 has addressed the question of how much weaker the seismic signal might be made. If the explosion occurs in a sufficiently large cavity there is no non-linear shock at all in the rock - that is, the walls of the cavity are never driven beyond their elastic limit. Such an explosion is called "fully decoupled", and theoretical work has indicated that signals could thereby be reduced by factors exceeding 100, compared to a tamped explosion. The cavity radius itself is the "elastic radius" for a fully-decoupled shot. For strong salt or granite, the cavity radius required for full decoupling has been estimated as about 20 meters times the cube root of the yield. For weak salt it is about 50% greater.

At frequencies that have conventionally been used for seismic monitoring, the seismic signal strength is proportional (very roughly) to the volume within the elastic radius. This volume is substantially reduced by fully decoupling, which is the reason why cavity decoupling has been proposed as offering the technical possibility of a clandestine program of nuclear testing. However, the signal strength is not nearly so strongly reduced, by decoupling, at frequencies above that associated with resonances of the internal surface at the elastic radius. In practice, the frequency above which decoupling is likely to be substantially less effective is around 10 to 20 Hz, divided by the cube root of the yield (in kt).

Of course, a thorough discussion of decoupling as an evasion scenario would have to include a number of non-seismological considerations. These include: the military significance of being able to carry out nuclear tests up to various different yield levels (e.g. 0.1, 1, or 10 kt.); and the political consequencies if a clandestine test program were uncovered. Technical considerations include methods of (clandestine) cavity construction, and the capabilities of non-seismological surveillance techniques.

It would appear that at sufficiently low levels of explosion yield some kind of clandestine testing could be undertaken that would be undetectable by seismological means. However, the technical difficulties associated with cavity decoupling rise rapidly with increasing yield. They would be formidable at 1 kt., but consider the requirements for hiding a fully-decoupling 10 kt. shot:

(1) The volume of the cavity would need to be at least 500,000 cubic meters, which if spherical requires a cavity diameter of 100 meters.

(2) Though such a volume (albeit non-spherical and hence not so efficient for decoupling) could be created in certain geological formations by dissolving salt in water and pumping out brine, the cavity would have to be protected against potential collapse subsequent to a 10 kt. blast (or at least, of concealing evidence of any collapse that might occur).

(3) Leakage of radio-isotopes must be prevented.

(4) Although decoupling by as much as a factor of 100 might occur in the frequency band conventionally used for monitoring, the decoupling factor drops by an order of magnitude at higher frequencies. From a fully-decoupled 10 kt. shot, the seismic signal level above about 10 Hz. would likely be easily detectable at, for example, NORSAR/NORESS (and/or at any other advanced monitoring sites, including seismic stations at regional distances, that might be in place at the time of the explosion).

For these reasons, testing could be clandestine only if conducted at limited yields. Clearly, that limit is far below the current threshold of 150 kilotons, even with current monitoring capability. It is, however, difficult to reach precise conclusions on what future yield levels could be achieved in a hidden test program, because much would depend on the level of commitment to improvements in current monitoring. It would depend too on the level of effort that might be put into the clandestine activity, and on assessments of the political risk of detection, which could be perceived differently by the monitored and monitoring sides. While some assert that clandestine use of cavity decoupling would be so difficult to execute that it belongs to the realm of fantasy, others have been persuaded that the risk might indeed be manageable, and that estimates of concealable yields, under this evasion scenario, must be made. Taking the latter more conservative approach, there appears to be a broad consensus among those seismologists who have studied the practical possibilities for evasion: given sophisticated monitoring that would include in-country arrays, it appears that explosions down to about the (decoupled) 5 kt. level could be detected and recognized as explosions. This conclusion, however, does not presume that the promise of high frequency monitoring will be fulfilled. If recent results, described here in Figures 8 - 12, are representative of what is possible with in-country stations, then monitoring down to the (decoupled) 1 kt. level appears achievable.

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Figure Captions

Figure 1. Annual numbers of nuclear explosions, detonated by six countries, from July 16, 1945, to April 30, 1986. Solid bars are used for atmospheric and underwater explosions; open bars for those underground.

Figure 2. (Upper) The different radiation patterns for earthquakes and explosions. Earthquakes involve shear motion along a fault plane. Explosions are compressional sources of energy, and radiate *P*-waves equally in all directions.

(Lower) Recorded signals (i.e., seismograms) of earthquakes and explosions have different characteristic features. Note the much stronger *P*-wave: surface-wave ratio, for the explosion as compared to the earthquake.

Figure 3. Contours showing detection capability of a particular seismic network of existing stations. For planning purposes, it is important that the estimated capability is in good agreement with the actual capability. Here, the differences are only about 0.1 m_b unit. (Ringdal, 1985.)

Figure 4. Attenuation of short-period signal amplitudes with distance. This figure is in m_b units, and so can be used to supply the distance correction needed to assign the m_b of a source as determined by observation at a particular distance. In forming $\log (A/T)$, A is the ground motion in microns, and T is the period of the largest part of the P - wave signal, in seconds. Distance here is measured in degrees, for the angle subtended at the center of the Earth by the source and the receiver. One degree is thus about 110 km measured over the Earth's surface. The figure indicates that m_b is zero for an event with about 1 millimicron of ground motion, at 1 s period, about 1000 km from the source.

Figure 5. The seismogram at Lajitas, Texas, due to a 5 ton chemical explosion about 725 km. away. This signal has been filtered to pass frequencies above 2.5 Hz. The conclusion associated with this record was that "a single, bore-hole, vertical seismometer at Lajitas could detect a fully decoupled .... nuclear explosion with a yield of about 0.2 kt at distances of the order of 750 to 1000 km. Processing ... could be expected to lower this threshold." (Herrin, 1985.)

Figure 6. (Upper) Location of the seismic array known as NORSAR, and a propagation path from the main Soviet test site. NORSAR consists of seismometer installations located in a circular region about 200 km in diameter. (Lower) NORSAR seismograms for a nuclear explosion, arranged as for a map view of the individual seismometers.

Figure 7. (Upper) The NORSAR beam for an Eastern Kazakh explosion (m_b 4.5).

(Lower) The beam for the above signal has been scaled down (or, equivalently as shown here the noise has been scaled up), to see how small an m_b could automatically be detected. The answer in this case is m_b 2.45. (NORSAR S.A.T.S.)

Figure 8. (Upper) NORESS seismograms, both single sensor and the beam, for an m_b 4.9 East Kazahk explosion on 25 July, 1985. (Lower) Spectra of signal and noise. To see the benefit of an array, as compared to a single sensor, compare the signal-to-noise $\boldsymbol{b - d}$ with $\boldsymbol{a - c}$. The improvement is at the lower end of the frequency range, because of the need (for an effective array) to have a coherent signal. Coherency degenerates at high frequency. (NORSAR S.A.T.S.)

Figure 9. Similar to Figure 8, but for a much smaller (sub-kiloton) explosion. The spectrum shows favorable signal-to-noise from about 1.5 to 10 Hz. Filtering the beam to pass signal in this band, gives the seismogram shown here. (NORSAR S.A.T.S.)

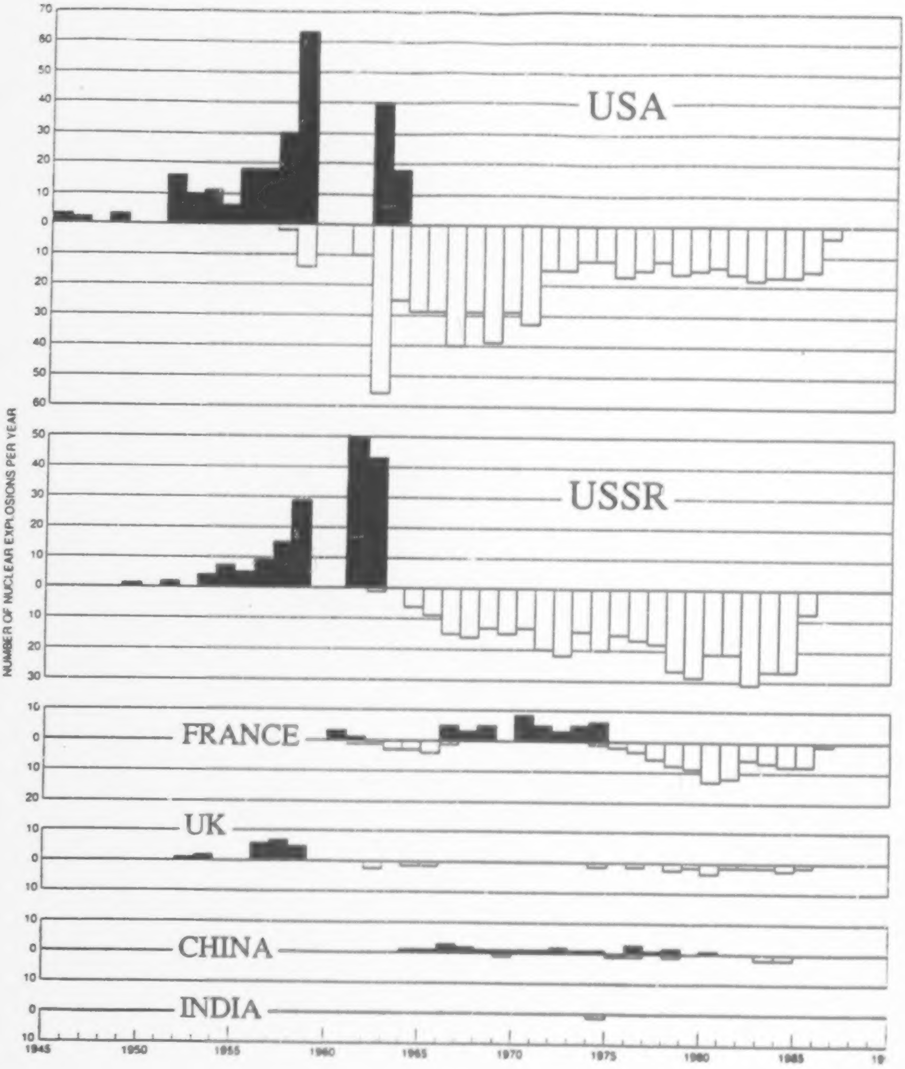
Figure 10. (Upper) Seismogram at a "regional distance" from the source. Signals here are associated with waves that propagate in the crust and uppermost mantle. (Lower) Seismogram at a "teleseismic distance." This wave has propagated through the deep interior of the Earth.

Figure 11. NORESS spectra of a presumed chemical explosion about 950 km. away. Signal for *Pn* is above noise out to 18 Hz. (NORSAR S.A.T.S.)

Figure 12. *P*-wave spectra obtained at a single NORESS sensor equipped with a special high-frequency recorder. The figure represents average features of about 100 regional events at various distances, all scaled to magnitude 3. A typical noise spectrum is shown as a dotted line. (NORSAR S.A.T.S.)

Figure 13. (Upper) M_s versus m_b for a suite of earthquakes and explosions (Marshall and Basham, 1972). (Lower) The body-wave magnitude is determined at two different frequencies (Stevens and Day, 1985). Earthquakes and explosions fall into separate populations on both these diagrams. Explosions are relatively efficient at generating higher frequencies.

Figure 14. m_b versus announced yield, for 17 Nevada nuclear explosions in hard rock. The best-fitting straight line here is $m_b = 4.067 + 0.74 \log_{10}$ (Yield), from which the standard deviation of these points is 0.08 m_b units. (Data from Nuttli, 1986.)


NUMBER OF NUCLEAR EXPLOSIONS PER YEAR
USA
70
60
50
40
30
20
10
0
10
20
30
40
50
60
USSR
50
40
30
20
10
0
10
20
30
FRANCE
10
0
10
20
UK
10
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CHINA
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INDIA
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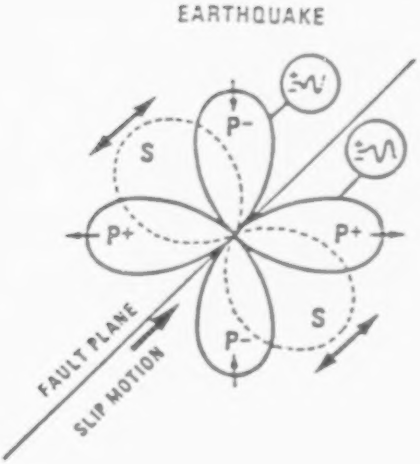
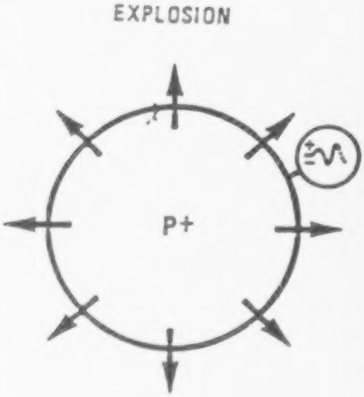
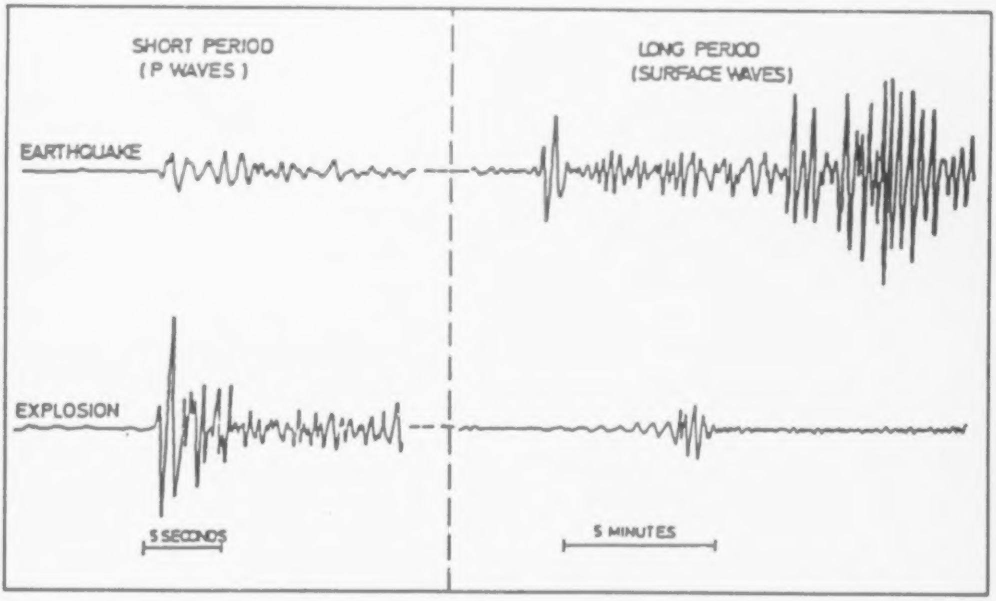
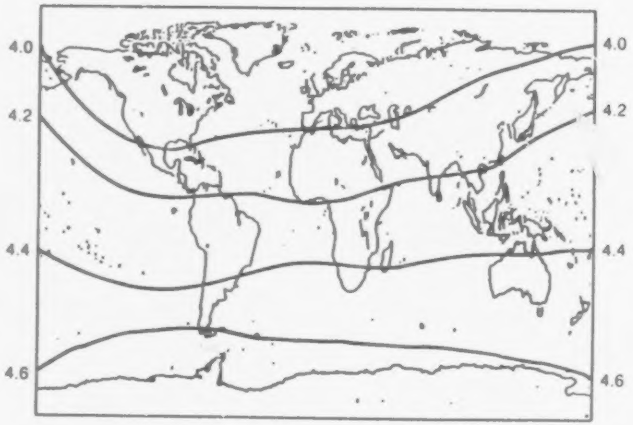
1960
1965
1970
1975
1980
1985
19

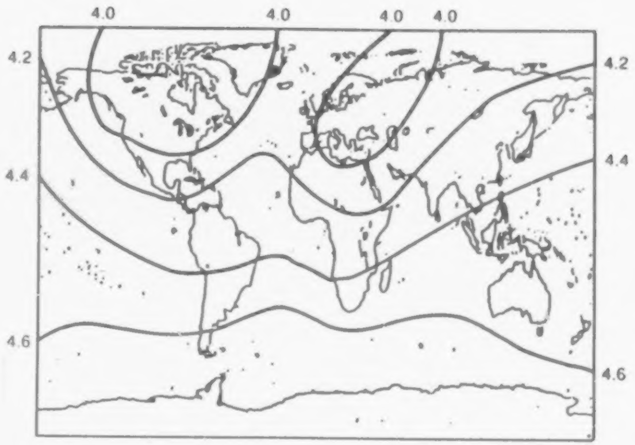

EARTHQUAKE
S
P-
P+
P+
S
P-
FAULT PLANE
SLIP MOTION


EXPLOSION
P+

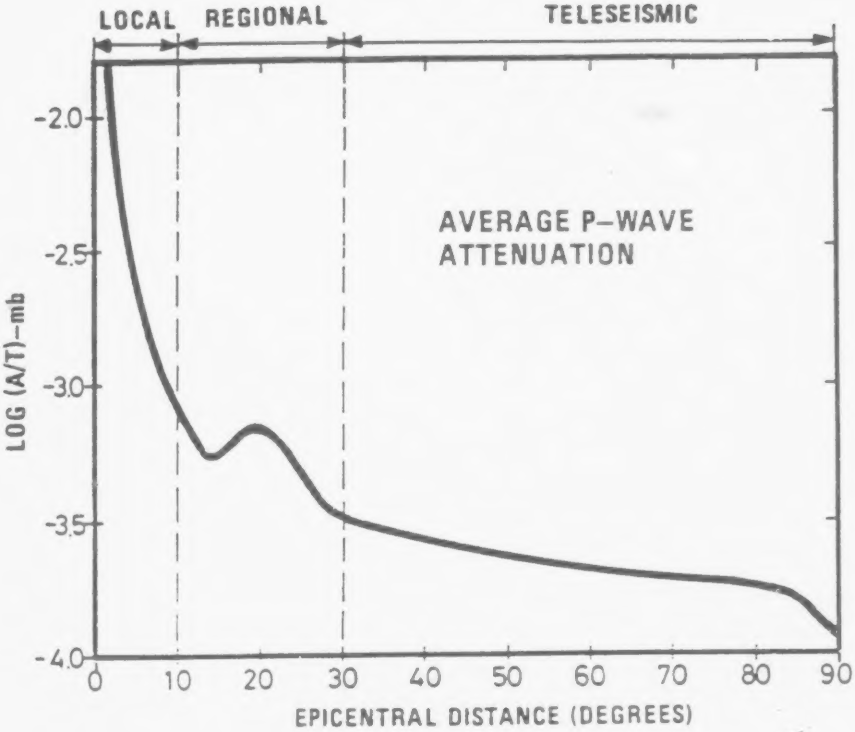

SHORT PERIOD
(P WAVES)
LONG PERIOD
(SURFACE WAVES)
EARTHQUAKE
EXPLOSION
5 SECONDS
5 MINUTES

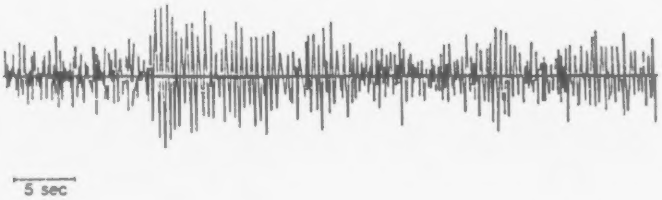

4.0
4.2
4.4
4.6
4.0
4.2
4.4
4.6

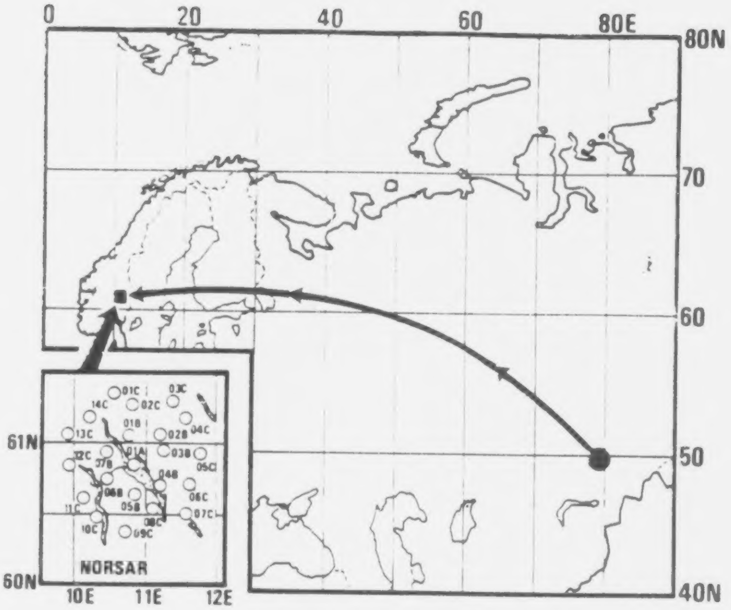
ESTIMATED

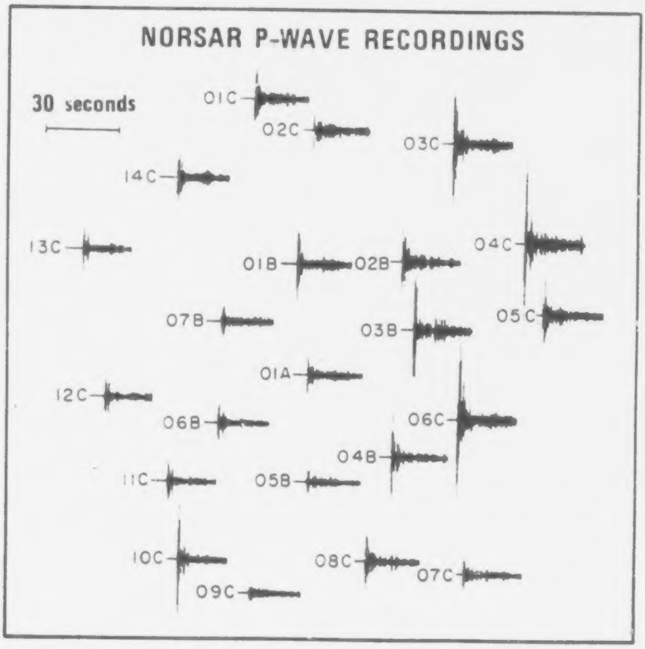

4.0
4.0
4.0
4.0
4.2
4.4
4.6
4.2
4.4
4.6

ACTUAL

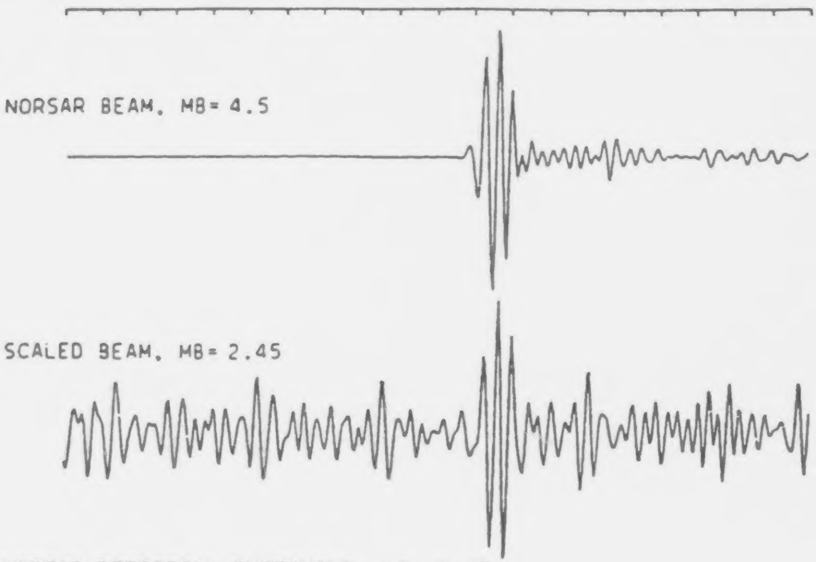

LOCAL
REGIONAL
TELESEISMIC
AVERAGE P–WAVE ATTENUATION
LOG (A/T)–mb
-2.0
-2.5
-3.0
-3.5
-4.0
0
10
20
30
40
50
60
70
80
90
EPICENTRAL DISTANCE (DEGREES)


5 sec

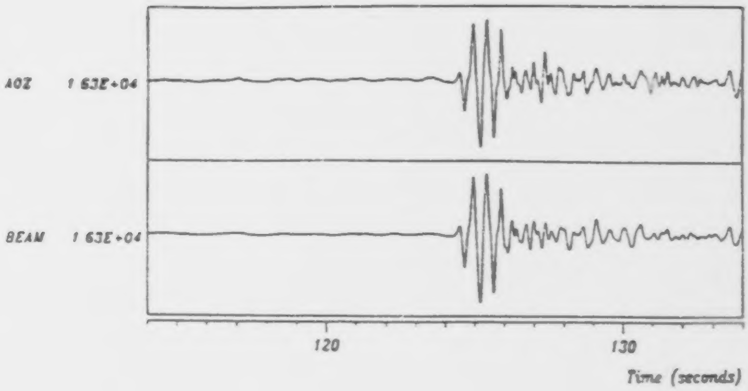

0
20
40
60
80E
80N
70
60
50
40N
61N
60N
10E
11E
12E
NORSAR
01C
02C
03C
14C
01B
02B
04C
13C
12C
07B
01A
03B
05C
06B
04B
06C
11C
05B
08C
07C
10C
09C

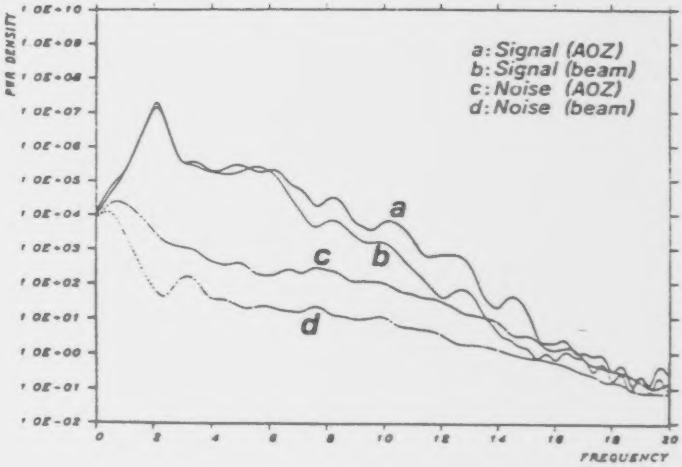

NORSAR P-WAVE RECORDINGS
30 seconds
01C
02C
03C
14C
13C
01B
02B
04C
07B
03B
05C
01A
12C
06B
06C
04B
11C
05B
10C
08C
07C
09C

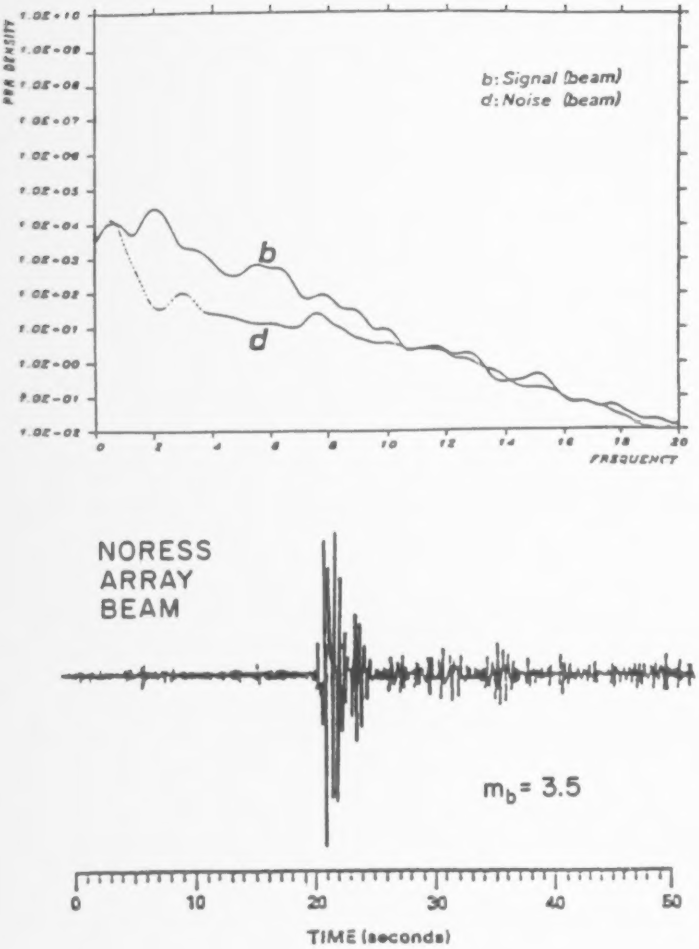
06/30/75 03.26.57.0 49.98N 79.05E MB=4.5
EASTERN KAZAKH
B-BP 2.0-4.0 20HZ 3RD



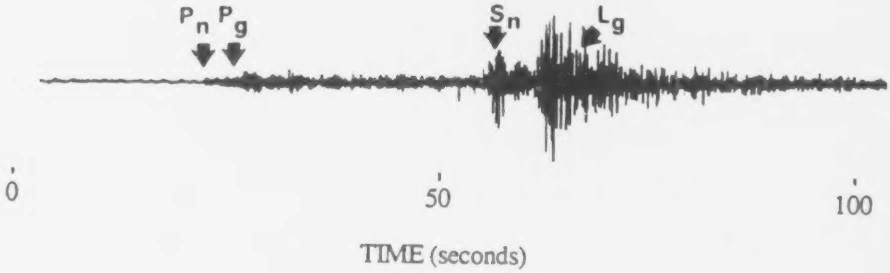
NORSAR DETECTION THRESHOLD: MB= 2.45

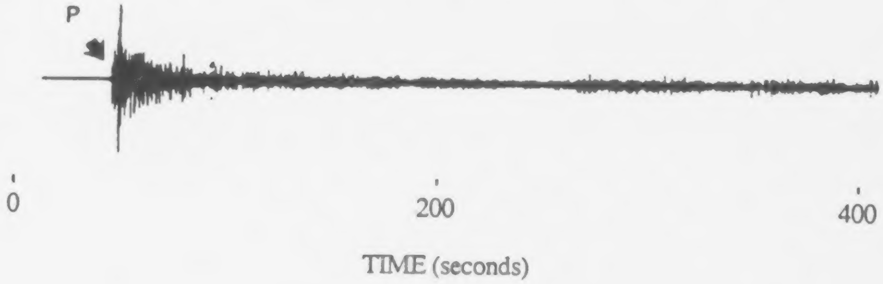

AOZ
1.63E+04
BEAM
1.63E+04
120
130
Time (seconds)

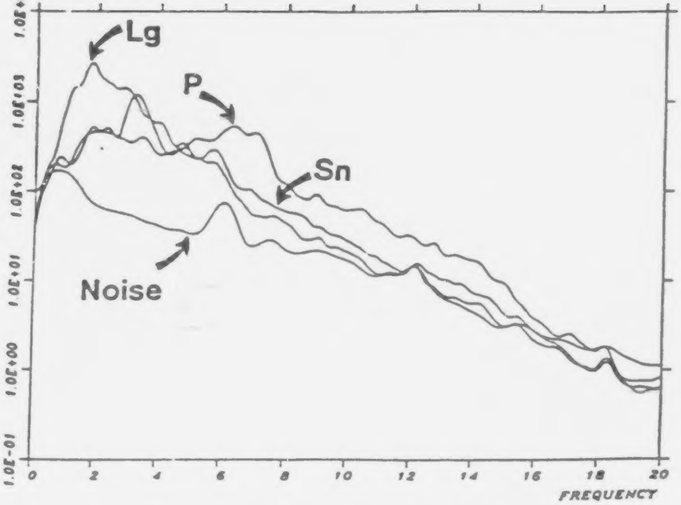

PWR DENSITY
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
0
2
4
6
8
10
12
14
16
18
20
FREQUENCY
a: Signal (AOZ)
b: Signal (beam)
c: Noise (AOZ)
d: Noise (beam)
a
b
c
d



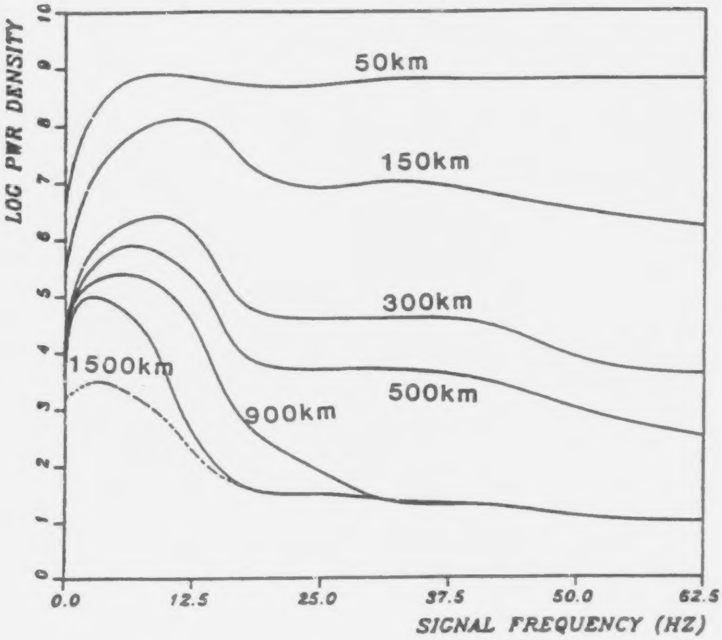
SIGNAL FROM SEMIPALATINSK, USSR, ON JULY 11, 1985.

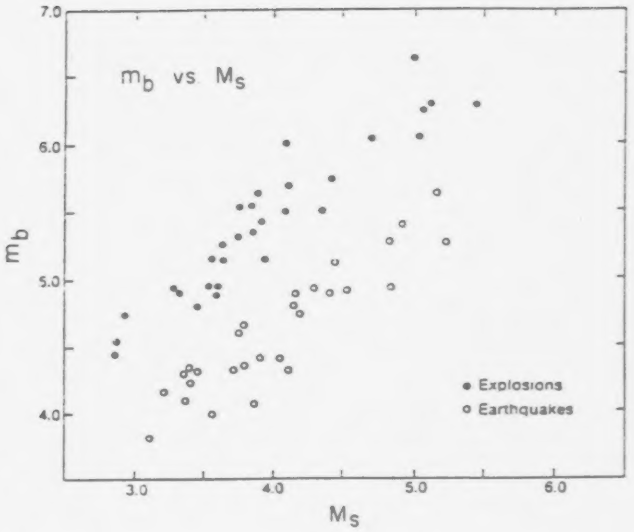

REGIONAL SIGNAL

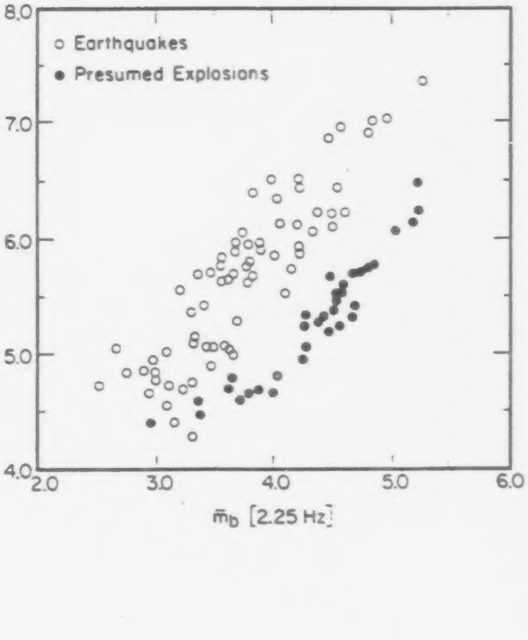

TELESEISMIC SIGNAL

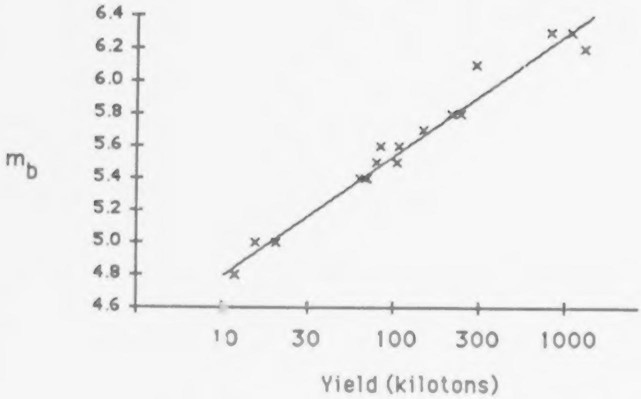


NORESS HIGH FREQUENCY RECORDINGS
SIGNALS SCALED TO MAGNITUDE 3.0




mb vs. Ms
7.0
6.0
5.0
4.0
mb
3.0
4.0
5.0
6.0
Ms
● Explosions
○ Earthquakes


○ Earthquakes
● Presumed Explosions
8.0
7.0
6.0
5.0
4.0
m̄b [0.45 Hz]
2.0
3.0
4.0
5.0
6.0
m̄b [2.25 Hz]


6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
m_b
10
30
100
300
1000
Yield (kilotons)

TOWARD A NEW TEST BAN REGIME

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Allan Lindh, Los Altos Hills, California

PROLOGUE

For most of the last 30 years, nuclear weapons have been developed and tested in a program of underground explosions that have occurred worldwide roughly two or three times per month. Recently, there has been renewed discussion on whether this testing activity should be restrained. And, if so, how should restraints be introduced and monitored?

This paper addresses the issue of a new test ban with emphasis on developing a practical compromise between those who advocate prompt negotiation of a comprehensive test ban, and those who advocate the *status quo*. The authors make a case for a Low Yield Threshold Test Ban Treaty, in which the threshold is lowered in stages over a period of years.

INTRODUCTION

In 1986, serious political attention returned to nuclear weapons testing as an arms control issue, after a lengthy period in which the subject attracted primarily specialist concern. Arguments for and against a Comprehensive Test Ban Treaty were reviewed in many forums in many countries. The Threshold Test Ban Treaty, signed in 1974 but still not ratified, was subjected to intensive debate in both political and technical arenas. The following list is an indication of this renewed interest, and gives some of the pressure points:

1. From August 6, 1985 to December 31, 1986, the U.S.S.R. observed a unilateral testing moratorium. Soviet testing is set to resume following the first U.S. test of 1987.
2. On August 8, 1986, in the U.S. House of Representatives, a 234 - 155 majority voted in favor of a defense authorization amendment to delete funding in calendar '87 for U.S. nuclear tests larger than one kiloton, provided the Soviets accept a similar low threshold and a U.S. monitoring program [1]. The Senate indicated support for test ban negotiations, but not in the form of restrictions on funding, and the House amendment was dropped in the days just prior to the Reykjavik summit meeting. However, the Administration undertook to submit in 1987, for the advice and consent of the Senate, the Threshold Test Ban Treaty and its companion the Peaceful Nuclear Explosions Treaty (signed in 1976 and also still not ratified).
3. Formal discussions began between the U.S. and the U.S.S.R. on technical aspects of verifying explosion yields from nuclear tests. The underlying issue is whether each side has tested above the 150 kiloton level allowed by the Threshold Test Ban Treaty. The Administration position is that this Treaty is not effectively verifiable but has likely been violated by the U.S.S.R. In open congressional testimony on April 29, 1986, spokesmen stated that U.S. official estimates of Soviet explosion yields had been recently reduced.
4. In the summer of 1986, seismic data from the vicinity of Semipalatinsk, the main nuclear test site in the U.S.S.R., became available under a non-governmental agreement between the Soviet Academy of Sciences and the Natural Resources Defense Council (a non-profit environmental defense group headquartered in New York). Even without nuclear explosions to monitor -- the Soviets still have a moratorium as of this time of writing, Jan 14, 1987 -- the data recorded from earthquakes and chemical explosions will help to answer longstanding

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[1] The Congressional Record of this debate, pages H5738 - H5756, may be the best widely available document, reviewing both sides of the many arguments that relate to nuclear testing - what it is for, and whether it should continue.

questions on signal-to-noise ratios and the capability of monitoring networks on Soviet territory to record and identify signals of small nuclear tests.

5. The Five Continent Peace Initiative was developed by leaders from Argentina, Greece, India, Mexico, Sweden and Tanzania, including a declaration on August 7, 1986, urging the two superpowers to undertake a "fully verifiable suspension of nuclear testing," and making a "concrete offer of assistance to achieve adequate verification arrangements."

6. One of the subsidiary groups of the U.N. Conference of Disarmament, a multinational negotiating body, made progress in the summer of 1986 on a technical issue associated with test ban verification. There is now consensus on planning an exchange by satellite of globally recorded seismic data, that will use methods far more sophisticated than have hitherto been acceptable in this multilateral forum. Several U.N. members, as part of their perceived U.N. responsibility, are planning new contributions to technical aspects of verification.

In considering this list of recent activities, it should be remembered that testing of nuclear weapons has gone on underground for about three decades. Thus, the first underground nuclear explosion occurred in Nevada in 1957. Code-named RAINIER, it was planned in part to see if nuclear testing could be done in an environment that permitted experiments dictated only by needs of the test program, unhampered by bad weather or by concerns over radioactive fallout. Seismic data from the earliest underground tests were intensively studied, and at that time it came to be recognized that in general the problems of explosion monitoring are more severe for tests conducted underground, than for tests in space, in the atmosphere, or underwater. In 1963 these problems appeared to many to be insuperable, a fact which contributed to the form of the Limited Test Ban Treaty, signed and ratified in that year, and banning signatories from nuclear testing in all environments except underground.

The detection of explosions, and their discrimination from earthquakes, is easier for events of larger size. This fact influenced negotiation of the Threshold Test Ban Treaty in 1974, intended to take effect after March 1976, and prohibiting any underground nuclear weapons test having a yield exceeding 150 kilotons. (Prior to negotiation of the 150 kt threshold, some underground tests had exceeded 1000 kt. A goal of the threshold treaty was to ban such tests, and in this it has succeeded. The Hiroshima weapon of 1945 was about 14 kt, and RAINIER was 1.7 kt.) This Threshold Treaty introduced a third technical challenge of importance in seismic monitoring, beyond detection and discrimination, namely the question of yield estimation; and whether this can be done accurately by seismic means. In 1974 the U.S.S.R. had ambitious plans to use nuclear explosions for re-directing major rivers from northerly to southerly flow, and for other civil engineering purposes. However, after 18 months of intensive negotiation it proved possible also to negotiate the Peaceful Nuclear Explosions Treaty of 1976, which extends the threshold of 150 kt on weapons test explosions to so-called Peaceful Nuclear Explosions (PNE's). Although both the U.S. and the U.S.S.R. have declared their intention not to exceed the 150 kt threshold, there have been reports that each country has raised questions as to whether the other side is indeed complying. Until the Soviet moratorium on underground testing began in 1985, each of the superpowers has tested since the early 1960's at rates in the range of about 10 to 30 times per year.

This brief history will indicate that technical capability to monitor explosions, or lack of such capability, plays a role in the development of policy options on weapons testing and/or arms control and the content of international treaties. Monitoring capabilities have significantly improved in the last ten years, and our paper is in part a discussion of the impact this might have in light of renewed interest in test bans, evidenced by the list of 1986 activities given above.

The major items on this list, in particular the first two, have led many to assume that there will shortly be changes in the currently allowed levels of nuclear testing, because agreement on a new test ban appears to be so widely desired. However, this sense that there will be progress, which in part is based on the view that verification is no longer of serious concern, will be challenged when relevant and very powerful institutions advocate continued testing. Opponents of a change in the *status quo* will surely state (as part of their perceived duty) that verification is indeed a problem. Given the complexity of political and technical issues, it may be that the serious debate on nuclear testing has only just begun.

From a broader perspective, opposition in the United States to a Comprehensive Test Ban centers around three main sets of issues; the aforementioned technical difficulty of verifying such a treaty, the possible strategic consequencies of abruptly terminating our nuclear weapons development programs, and the need for a test program to assure confidence in the stockpile and to study blast and radiation effects on military hardware. Outlined below is an alternative approach to restricting nuclear testing that addresses all three of these concerns, within a context that allows for the fears and phobias of the Soviets as well. The intent is to outline a treaty proposal that is gradual in its implementation, so that the fears of all parties are minimized; but that, though modest in its short-term goals, is sufficiently realistic in what it attempts to accomplish that it has a chance of surviving over the long term.

Unfortunately, rational discussion of limitations on nuclear testing is made difficult by the degree to which opposing positions are so very strongly held on almost all issues that bear any relationship to the main question. For some, the hope of constraining nuclear testing, and thereby slowing down nuclear weapons development, has taken on almost sacred connotations. Others feel just as deeply that it is appalling to consider tinkering with the arms race, even in areas where the U.S. may be a few years ahead, and thereby risk upsetting a balance that has deterred world war since 1945. In addition, rational discussion is made difficult because it takes some effort for those not directly involved, to acquire enough knowledge about the details of nuclear testing and monitoring to develop an informed opinion.

However, if public pressure for some kind of new test ban continues to grow as it did in 1986, it is natural to persist in asking what might be possible. For further restraints on testing to be imposed, compromises will have to be found on many of the points of disagreement, and some of the relevant constituencies in the U.S. and U.S.S.R. will have to defer or lose some cherished goals and adapt to new ideas. Our outlined approach attempts to address the traditional positions held on either side of the test ban debate, in the belief that prudent compromises can be formulated that protect U.S. national security interests while enhancing mutual security and international stability.

Thus, the pages that follow outline a staged approach to a Low Yield Threshold Test Ban Treaty. It sketches an approach that has some appeal to those who regard a Comprehensive Treaty as a long-term goal. In addition to reconciling some of the U.S. internal conflicts over nuclear testing, it strikes a balance between the widely different positions currently taken by the U.S. (that we need greater verification for the current unratified Threshold Treaty at 150 kilotons) and the U.S.S.R. (that a Comprehensive Test Ban is verifiable and should be easily negotiated). We propose that the present yield threshold should be moved down in stages over a period of several years, with commitment to an eventual low value in the forseeable future, and retaining the concept of a comprehensive test ban as an eventual goal. Improved verification may be added whenever the threshold is reduced, with the intent of ensuring that the next threshold reduction would result still in a verifiable treaty. The advantage from the U.S. point of view is that at each step, verification capability is demonstrated for a new reduced threshold before that threshold is set. For both sides, it has the advantage of setting long-term goals and working gradually towards them.

We recognize that such an agreement might be viewed as less than half-a-loaf by those committed to adoption of stringent arms control measures as soon as possible. However, we believe that an attainable half-loaf is vastly preferable to an indefinite perpetuation of the stalemates that now exist.

We should note that monitoring a temporary moratorium may present considerations that are different from treaty monitoring. A moratorium usually has closely-related proposals for the future that would be jeopardized by the least indication of non-compliance, so pressures toward compliance are built in and monitoring is less of a problem. The discussion here concerns monitoring a treaty of unlimited duration.

OUTLINE OF A STAGED TEST BAN TREATY

1. Work from drafts agreed to in 1980, but change them from a Comprehensive Treaty to a Yield Threshold Test Ban Treaty with an initial threshold of 16 kilotons. Even though such a threshold was not envisioned in 1980, retain and deploy the internal seismic networks agreed to in principle at that time for monitoring a Comprehensive Test Ban.

2. Add a provision for Treaty Review after 5 years, to consider lowering the threshold to 4 kilotons; but with each original party reserving the right to veto that reduction. As part of the decision on whether or not to reduce the threshold, a review of networks would be undertaken at the request of any original party to the Treaty, requiring agreement on augmenting and/or changing the networks as a basis for deciding whether to accept the threshold reduction.

3. Add a provision that: after the first review and reduction (if agreed to), the threshold would be subject to further reduction to 1 kiloton after another 5 year interval, with each original party retaining the right to veto the reduction; and the right of requesting a network review, with agreement required on improving the network (if deemed necessary) as a basis for deciding whether to accept the threshold reduction.

4. Add a provision that the eventual threshold, as perceived at the time of original signing, would be 1 kiloton; but that this number, and/or the length of time between threshold reductions (5 years) could at any time be reduced upon agreement between original parties to the Treaty. A Comprehensive Test Ban would be acknowledged as an eventual goal, but without specification of the date.

5. Each side would be allowed at most one test site at which testing within the current threshold may take place, and allowed tests would have to be at sufficient depth of burial in hard rock, and/or sufficiently below the water table, to promote accurate seismic yield estimation and absence of above-ground radioactive gases and particulate debris.

6. Decoupling experiments would not be permitted for events above 1 kiloton. It must be recognized that any nuclear explosion decoupling experiments, even at yields below 1 kiloton, would threaten the Treaty.

ADVANTAGES OF A STAGED APPROACH

THIS PARAGRAPH COULD NOT BE READ IN FROM DISK

THIS PARAGRAPH COULD NOT BE READ IN FROM DISK

1. Real-world experience with internal seismic stations, with their natural and cultural noise levels, and with variations in those noise levels.
2. Real-world detection and discrimination experience at a threshold where external networks and other National Technical Means provide cross-checks. It may be anticipated that explosions larger than 1 kt would be well recorded both inside and outside the territory of a testing nation.
3. An opportunity to accumulate well-calibrated seismic amplitude data within the Soviet Union. This would include signals from quarry blasts and from local and distant earthquakes, in addition to underground nuclear explosions. Taken together these data would reduce uncertainties concerning the structure and properties of the crust and upper mantle in the U.S.S.R., and thus reduce uncertainties in seismic yield estimation.

A related advantage of a gradual approach would be the absence of problem events that would have to be dealt with in the beginning. (The term "problem event" is used for a detection about which there is uncertainty as to whether it is an explosion or an earthquake.) At the initial threshold there would be little problem with chemical explosions. But such explosions, for mining or other mantle in the U.S.S.R., and thus reduce uncertainties in seismic yield estimation.

A related advantage of a gradual approach would be the absence of problem events that would have to be dealt with in the beginning. (The term "problem event" is used for a detection about which there is uncertainty as to whether it is an explosion or an earthquake.) At the initial threshold there would be little problem with chemical explosions. But such explosions, for mining or other engineering purposes, are a genuine problem at lower yields [2], and time is needed to assess possible solutions such as: a program of on-site inspection; the effect of required prior announcement of all chemical explosions above a specified size; and the contribution to verification of a network of in-country radiochemical monitoring stations.

By avoiding prior commitment to a comprehensive test ban by a specific date, there is avoidance of the criticism that the U.S. would be committing itself to an unverifiable treaty. "Comprehensive" is a strong word, and a respect for the meaning of precise language requires some acknowledgement that it is not yet clear how a truly Comprehensive Test Ban Treaty can be monitored. For example, one can conjecture an evasion scenario in which a few 0.05 kt chemical explosions are set off at the same time, and near the same place, as a 0.01 kt nuclear test. Though such a scenario, and others equally exotic, would carry great political risk for little military gain, it is a procedure that will be regarded as seismically undetectable. But, the argument over such minor concerns need not be allowed to prevent advantage being taken, if desired, of present capabilities to monitor easily at higher yield levels that still are far below the current 150 kiloton threshold.

Perhaps the feature of a staged approach that is most appealing to those seeking some restraint on nuclear weapons development is that by attempting less in the beginning it facilitates eventual progress. In the early stages it would be symmetrical with regard to continued testing, research, and training of physicists. To the extent that, at later stages, the threat of asymmetries is perceived, scheduled threshold reductions at that time can be vetoed. A staged approach protects the national investment in expertise and ongoing research programs at the Weapons Labs. For a period of several years it would have no impact on tactical weapons development, but might have some effect on stockpile testing. It would affect attempts to develop third generation nuclear weapons, but the Strategic Defense Initiative is declared to be a non-nuclear program. To the extent that claims of Soviet research on nuclear-pumped X-ray lasers have prompted the U.S. to pursue this technology too, both superpowers would be restrained together in this area by a Low Yield Threshold Test Ban Treaty. The direct impact on strategic weapons programs would be gradual, and for decades the testing and research infra-structure could be held intact. To the extent that in the long term a one kiloton Threshold Test Ban Treaty or a Comprehensive Treaty is seen as a reality, weapons designers would have the required years of R and D to accommodate to the new regime. It must be recognized that of itself a ban on testing cannot, for several decades (if ever), significantly affect the size of strategic arsenals now in place.[3]

And finally an advantage of a staged approach is that it addresses the trade-off between relatively short-term national security concerns and the long-term risk of nuclear war. While some have argued that a Comprehensive Test Ban would soon upset the strategic balance (e.g. by placing greater reliance on conventional forces), others have focussed on the long-term risk of nuclear weapons eventually being used and believe that we owe it to future generations to start rolling back the nuclear arms race. A staged approach addresses both these concerns by providing a transition

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[2] Preliminary enquiries to suppliers of chemical explosives indicate that, in the U.S., a 0.1 kiloton chemical explosion occurs on average about once a day. However, these occur at a limited number of mines.

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[3] This fact may restrain policymakers who want to see rapid progress on a Test Ban Treaty, from following the fastest path promoted by those most optimistic on verification issues. Going "all out" for a stringent test ban as soon as some perceive possible, would place such stress on other aspects of strategic planning that collapse of this approach would likely occur before ratification even if such a treaty could be negotiated and signed. The point here is that, even if this approach resulted in an effective test ban, it still does not succeed in reducing the threats of large stockpiles. The alternative is a slower staged approach that does limit the qualitative development of new nuclear systems. Of course, another reason why going "all out" risks failure, is that the debate would be side-tracked into contentious verification issues. Even when verification is possible, there is the problem that it may not widely be seen to be possible. And, it will take years to emplace a good monitoring system. (A recent review of future possibilities in nuclear weapons development, which could be restrained by a new test ban regime, is given by Theodore B. Taylor in the November, 1986,

Bulletin of the Atomic Scientists.)

period during which the impact on deterrence of phasing out testing can be assessed with minimal risk of upsetting the strategic balance, yet still imposing a restraint on nuclear development programs that at present are checked only by the unratified 150 kiloton Threshold Test Ban Treaty. Only a treaty that meets both these concerns and is widely seen to be verifiable can have a chance of surviving the storms that will inevitably occur in coming decades. What is offered by any test ban treaty is implicit recognition that unrestricted nuclear weapons development is itself a threat. This is the central issue. The intent of this paper is to help in discussion of the central issue, which need not be obscured by concern over monitoring capability.

DISADVANTAGES

A staged Threshold Treaty that starts at 16 kilotons will attract vigorous opposition both from those who want no restraint and from those who advocate much more (e.g. an immediate Comprehensive Test Ban), so it would be promoted only by moderates who are prepared to compromise. But it implicitly assumes that over the next one or two decades it will be possible to introduce a major new element of "management" into the arms race, and that this new element would have a significant impact. Would such a treaty have supporters in sufficient numbers to carry it through the difficult steps of further definition, negotiation, and ratification?

To meet their perceived responsibilities, weapons designers would probably want a large program of tests to be held at yields just below the threshold, whatever it was at the time, thus putting pressure on verification technologies associated with yield estimation. This problem is hard to avoid, even with a quota on testing.

The last paragraph of the treaty outline proposed above, concerning decoupling experiments, will be seen by some as merely advocating good behavior, and thus having no place in a formal treaty. The intent is to recognize explicitly a technique (i.e. the building of cavities and their use for muffling explosion signals) that could undermine verification provisions on yield estimation. Fortunately, use of the technique might well be detected, even when it succeeds in preventing accurate yield estimation. Though this is not the most important component of the treaty, it could well prove one of the most difficult to tie down.

The complexity of a staged approach will be noted, as compared to the simplicity that some see in a comprehensive treaty. Thus, most advocates of a Comprehensive Test Ban Treaty have recognized that monitoring breaks down at very low yield levels, but say that this is not an important issue. It merely requires clarification of the level down to which a "comprehensive" treaty can be monitored, and a political judgement as to whether this is in some sense adequate. From this perspective, use of the word "comprehensive" would still be appropriate and monitoring for it would be satisfactory, if it described a test ban in which "all explosions of direct military significance" would be identified. To the extent that very small explosions might go unidentified or even undetected, a comprehensive treaty would then be called "adequately verifiable" if clandestine activity could occur only at levels judged to have "very minor military significance." Monitoring capability would be "good enough", if it could drive the kiloton level of undetected infractions down to values so low that the disadvantages of their possible existence would be outweighed by the perceived advantages of banning almost all testing of the type carried out in recent years. Such an approach would appear to avoid the technical questions of yield estimation when reviewing treaty compliance. The avoidance lasts as long as there is no detailed interpretation of the phrases placed as quotes in the preceding sentences. A staged threshold treaty thus appears more complex, in part because it does more explicitly allow separate discussion of the two sets of technical issues associated with (a) what military significance attaches to testing at different yield levels; and (b) what monitoring assets must be developed and deployed to ensure that pre-specified requirements are met. If the staged approach were adopted, it would substantially change current levels of U.S. and (pre-August 1985) U.S.S.R. nuclear testing; and at the later stages (when the threshold was down to 4 or 1 kiloton, and much practical experience had been gained with in-country monitoring) it would potentially present itself as a test ban regime that allowed the option of conversion to a comprehensive ban. Note, however, that a comprehensive ban could consistently be identified as the eventual goal of a staged approach.

COMMENT ON MONITORING ISSUES

There has been much recent discussion of improved techniques for monitoring underground explosions (e.g. by using high-frequency seismic waves). There is a need to have this work reviewed carefully within the technical community, and the Office of Technology Assessment has begun to undertake a role here. But let us assume (for purposes of understanding the consequences) that at least some of these methods are effective. What must then be discussed, is the question of how they will be implemented.

The situation would be somewhat like having a few good telephones. The question then becomes: how does one design, install, use, and instill confidence in a large telephone network, that will meet pre-specified high-performance requirements? Surely, it has to be done in stages.

It truly is going to be a large undertaking, if it is to be seen by all serious constituencies that seismic monitoring is done correctly for a new nuclear test ban. Confidence that monitoring is being done well is not built just by following the principles that underly a successful research institution (i.e. following your best scientists, because they are most likely to have the best new ideas). Rather, it is built on years of experience within a community that is careful with details and is structured so that it can and must respond to all serious critics. At present, there is no single location in the U.S. government where the new and large monitoring program should obviously be organized.

To expand on this point, consider what is needed to execute the best that modern seismology can accomplish in monitoring. It must pull together:

(a) massive expertise in the geology of the U.S.S.R., and massive expertise too in regional seismology in areas quite unlike the western U.S.;

(b) a framework for decisions in building and operating a system that would entail expenditures above $100,000,000 per year in some years; and

(c) access to the wide diversity of international seismic data, on a timely basis.

(d) It must be able to carry out a few key analysis procedures in secrecy, with access to senior policy makers who may not like the numbers they are being offered. This is the centuries-old problem of how to maintain a competent intelligence function when occasionally it may have to convey bad news. But the monitoring institution must recognize that most expert seismologists work totally outside the classified community, and yet have much to contribute.

(e) It must solve certain technical problems that have not yet had to be addressed, including: (i) Yield estimation for small events (as contrasted with those of significance under the present 150 kiloton threshold regime). (ii) Yield estimation from regional seismic waves such as Pn, Sn and Lg. (A "regional" seismic wave is one observed at relatively short distances, less than about 2000 km. This is contrasted with "teleseismic" waves, observed beyond 2000 km. Quite different analysis techniques are required for the two wave types.) (iii) Uncertainty of yield estimation when partial muffling of seismic signals might be suspected.

Note that the burden here, if future threshold reductions are to be demonstrably monitorable, would be on seismologists and other scientists to continue to make technical advances - an activity that would be promoted if high quality records from the internal networks were made available. This would attract the nation's best seismologists to return to the study of explosion detection and discrimination, bringing a problem-solving mind set. In the 1960's, the attraction of applying a problem-solving approach in a field of international importance drew the leading seismologists of the day from industry and academia toward monitoring research. But what was then achieved was not enough, or not at the right time, to translate into anything effective, and many of them moved into other specialities related more to earthquakes or to exploration for oil than to explosions. The style of seismic monitoring research changed in the 70's and 80's, concentrating on building up massive data bases with better instrumentation, and continued small improvements in analysis methods. Capabilities for monitoring small explosions[4] have clearly improved, but no forum has developed in which these capabilities can be thoroughly reviewed and (if necessary) guided toward further improvement using the best techniques available.

Indeed this will all take time. When discussion of technical issues is rushed, and a mistake is made, it takes a long time to recover. For example, consider the monitoring network designed in 1958 and known as the "Geneva System." A plan was hastily written that was proven to be flawed a year or two later. In the eyes of many policymakers, seismology has never recovered from the bad reputation it acquired in those days. Note that it took years to gain general acceptance of the effectiveness of m_b:M_s as a discriminant (i.e., comparison of seismic body wave/surface wave amplitude ratios, to distinguish between earthquakes and explosions); and years to get a consensus in the technical community on yield estimation for large explosions. In the opinion of many, a "problem-solving" approach will not develop until monitoring is in the hands of an agency or institution that (for reasons stemming from its main mission) wants to solve the relevant technical questions. It is therefore not unfair to assume that seismic monitoring cannot be left solely to the Department of Defense or the Department of Energy, which are among the few agencies that have adequate budgets to do the job well, and which indeed have sponsored creative R and D in this area; but which have as part of their main mission the duty to design, build and deploy nuclear weapons, and to plan for their use. Stated this way, it will be understood that in some quarters there is inbuilt resistance to developing better monitoring capability.[5] Possibly, progress could come from leaving expensive items with these agencies (i.e. instrument deployment, routine data-gathering), and giving the more sophisticated additional analysis to a Center for Seismic Studies that reported to the State Department or the U.S. Arms Control and Disarmament Agency (ACDA). The act that set up ACDA gives it these kinds of responsibilities, but in the two and a half decades since this agency was founded they have never been assumed. ACDA now has a budget of only about $30 million (about 400 times smaller than that of DoE, and about 10000 times smaller than DoD). It would greatly assist the discussion of monitoring issues, if some funds were transferred for research in this area under the sponsorship of an agency that took a problem-solving approach. However, though it is easy to make this point, implementation would be difficult. For example, an agency such as the U.S. Geological Survey (USGS), with a reputation for technical excellence generally in seismology, could apparently contribute much to a new monitoring program. Yet that very reputation could in practice be at risk over a period of years if the USGS were to become known for vigorous work with implications for arms control - an area not related to that agency's main mission within the Interior Department.

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[4] By "small" here, is meant "down to about 0.01 kiloton fully tamped, or about 1 kiloton decoupled." Many examples exist, of small (i.e 0.002 - 0.005 kiloton) explosions in quarries and boreholes, observed out to several hundred kilometers. Indeed, this provides a standard method for acquiring geophysical data on the structure of continents. Such field experiments usually try to maximize the coupling of signal into the ground, although they rarely have the sophisticated instruments and installation techniques of a first-rate monitoring network. An array of seismometers in Norway has a detection threshold of around m_b 2.5 for much of the U.S.S.R., and picked up a m_b 3.5 explosion (i.e. sub-kiloton) at Semipalatinsk in July 1985 with a signal-to-noise ratio of about 30. These sensors were 3800 km. from the explosion: an in-country array, at a "regional" rather than a "teleseismic" distance, could pick up signals from far smaller explosions. The principal technical problem of practical concern in monitoring explosions lies in overcoming the possibility that decoupled explosions at around 1 - 10 kilotons could go undetected and/or unidentified. This is an active area in verification research, and proposed solutions that rely on use of high frequency seismic waves may be confirmed by the data generated once in-country seismometers are in place.

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[5] See the statement from a Department of Energy spokesman in SCIENCE, 26 September 1986, page 1367: "The Administration has stated that a test ban or moratorium is not now in the national security interests of this country, and the Department of Energy would not support or fund any effort that is contrary to Administration policy." An Assistant Secretary of Defense has referred to the recent non-governmental agreement, under which U.S. seismologists have instrumented sites near Semipalatinsk, as "an absurd private excursion," though it is providing hard information on noise

levels and seismic wave-propagation characteristics in a region to which the U.S. has never before had access.

Finally, a few further comments are needed on one new technical issue that will arise whenever a Low Yield Threshold Test Ban Treaty is given serious consideration - namely, the question of accuracy of seismic yield estimation when yield is low. It is clear that this is becoming a contentious verification issue. At present, for explosions of concern with respect to the 150 kiloton threshold, a "factor of 2" uncertainty is commonly quoted. By this is meant, that the seismic yield estimate (sometimes called the "central value yield"), when multiplied and divided by 2 (the "factor of uncertainty"), gives a range of yields within which one has confidence that the actual yield really does lie. This level of confidence can itself be expressed as a percentage, usually taken as about 95% in seismology (as may be inferred from usage of plus and minus "two sigma" to designate the range within which yield is expected to lie). However, a value of 2 for the factor of uncertainty is not a fair summary of current capabilities, because it refers only to one type of seismic method, and for large explosions there are typically three or more independent seismic waves upon which separate seismic yield estimates can be based. If the average of these estimates is taken as the central value yield, with a factor of uncertainty of 2 (at the 95% level) for each of three methods, it is easy to show that the resulting seismic yield estimate has only a factor of 1.5 uncertainty.[6]

The above technical discussion requires modification for small explosions because of possibilities of full or partial decoupling. ("Decoupling" is the term for emplacing the explosive device within a cavity large enough that seismic signals are muffled, with the effect that the seismic yield estimate could be too low unless the amount of muffling is itself correctly estimated.) This introduces an extra element of uncertainty for small explosions because for them decoupling is relatively easy to execute. (At 150 kilotons, even partial decoupling is impractical. There would be little effect unless the cavity had a radius greater than thirty meters, the construction of which, in association with what would still be detected as a very large explosion, would be unlikely to go unnoticed.) Thus, a DoE spokesman (Admiral Foley) has recently said the yield uncertainty could be as much as a factor of 20 for small explosions. The problem cannot be denied, though it arises only in the context of explosion signals that are already very small. For example, a 0.2 kiloton event might be decoupled to send out seismic signals like one of only 0.01 kiloton, which might still be detected by a good network of in-country stations. It is because of this problem, for smaller tests, that the phrase "sufficient depth of burial in hard rock" appears in the outline treaty proposed above. The technical community needs further discussion of this issue, to explore: how constraints on testing environment can be defined (to prevent partial decoupling); or, absent satisfactory constraints, how yield estimation would actually be affected; or, what are the levels of yield at which increased uncertainties have military significance.

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[6] This is interesting in connection with the uncertainty widely quoted for CORRTEX, a relatively new but relatively intrusive technology, in which the explosion-induced shock wave within a few meters of the shot-point is monitored in space and time. This method provides yields "that are accurate to within 30%." The more precise statement of this uncertainty is, apparently, that the range of plus and minus 30% is also stated at the 95% confidence level that is the convention in seismology. This range is equivalently described by a factor of uncertainty equal to 1.3. Thus, the comparison between CORRTEX capabilities and seismic capabilities for yield estimation appears to be roughly between factors 1.3 and 1.5. Even this is not the end of the story, for in the context of a ratified Threshold Test Ban Treaty extra information would be available that could improve seismic methods. Note too that because CORRTEX is a relatively new technology, the "factor of uncertainty" at a specified level of confidence is probably not yet well known, although for explosions above 50 kilotons it probably is eventually capable of yield estimation more accurate than use of regional or teleseismic signals. But CORRTEX may suffer more than seismic methods from the problem of an increased level of uncertainty in yield estimation at low yields.

Note that if the level of confidence is stated at less that 95%, then the range of yields within which the actual yield lies (at that lower level of confidence) is narrowed. Equivalently, the factor of uncertainty is assigned a lower value. Thus, the factor of uncertainty must be stated in association with some specific level of confidence. It turns out that a factor of 2 for a 95% confidence level is the same degree of uncertainty as a factor of 1.25 for a 50% confidence level. (Seismic amplitudes for a suite of explosions at fixed yield are log normally distributed.)

Discussion of these issues will be needed to set a rational basis for choosing the initial new low threshold. We reiterate, this is subordinate to the main issue of whether to seek a new test ban, which will be settled politically after a review of national security concerns that will be heavily influenced by military needs. But, the technical issues of monitoring, raised here, are nevertheless relevant to the discussion of policy options even before the main issue is resolved. This paper can be called a worms-eye view of nuclear test bans. In the above outline the initial new low threshold is taken as 16 kilotons, which would subsequently be reduced to 1 kiloton in two stages. At 16 kilotons, uncertainty of yield estimation is not likely to be much different than for tests of concern with respect to the current 150 kiloton threshold. (A cavity more than 10 meters in radius would be required to reduce the typical 16 kiloton signal to that of a normal 8 kiloton signal - an exercize in partial decoupling that, on the single allowed weapons test site, would presumabably not go unrecognized.) Detailed technical review plus political consideration of the standard of adequacy (for uncertainty of yield estimation) might lead many to conclude that sufficiently accurate seismic yield estimation is possible (with current monitoring networks and some controls on testing environment), with the initial new threshold set at 8 or 4 kilotons. The technical goals, for in-country stations, would include improved accuracy of yield estimation, at low yield. If (for example) non-nuclear calibration shots could be negotiated, then, from seismic waves observed at regional distances on in-country stations, yields of Soviet nuclear explosions could possibly be estimated by the U.S. (by non-intrusive seismic methods alone) with accuracy eventually approaching that obtainable seismically now for Nevada explosions. The factor of uncertainty could then approach about 1.3, at the 95% level of confidence, for explosions of more than 10 kilotons.[7] On the question of Soviet compliance with the 150 kiloton threshold during 1976 - 1985, much further information will become available if in-country stations are deployed, which will help to clarify the interpretation of old data from external stations.

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[7] See the paper by Otto Nuttli, Journal of Geophysical Research, February 10, 1986, pages 2137-2151: one sigma for the data points that determine Nuttli's Lg magnitude - yield curve for Nevada is 0.05 magnitude units, translating to a 30% error in yield, near 150 kilotons, at the two sigma level.

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MONITORING YIELDS OF UNDERGROUND NUCLEAR TESTS

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INTRODUCTION

The United States and the Soviet Union signed the Threshold Test Ban Treaty (TTBT) in 1974 and the Peaceful Nuclear Explosions Treaty (PNET) in 1976. These treaties prohibit underground nuclear explosions having yields greater than 150 kilotons (kt). Although neither party has ratified either treaty, both have separately stated that they will respect the 150 kt limit.

Previously, the Reagan Administration has not sought ratification of these treaties on the grounds that "we cannot effectively verify Soviet compliance with the 150-kiloton threshold on underground nuclear explosions. The remote seismic techniques we must rely on today to monitor Soviet nuclear tests do not provide yield estimates with the accuracy required for effective verification of compliance."[1] Yield estimates based on teleseismic body wave magnitudes (the method currently used by the U.S. government) are considered to be uncertain by a factor of two at the 95% confidence level.[2] This statement means there is one chance in 40 that an explosion with a most likely yield of 150 kt actually had a yield of 300 kt or more. This uncertainty was apparently considered acceptable at the time the TTBT was signed. As discussed later in this report, the best remote seismic methods now available have, according to some experts, an uncertainty of a factor of 1.5 at the 95% confidence level.

Recently, and in accordance with his agreement with the Congress just before the Reykjavik Summit, President Reagan has proposed ratification of the TTBT and PNET with reservations that they not go into effect until the Soviet Union agrees to new monitoring measures to improve verification. The Administration is strongly advocating adoption of the hydrodynamic method of yield estimation, which involves measuring the way in which the shock wave produced by an underground nuclear explosion propagates away from the point of detonation. In particular, the Administration advocates[2] use of the so-called CORRTEX technique for measuring the radius of the shock front as a function of time (CORRTEX is an acronym for *continuous reflectometry for radius versus time experiments*). It believes that it has identified in the hydrodynamic yield estimation method an approach "which will reduce the uncertainty in yield measurement to an acceptable level and will do so without danger of compromising other sensitive information about the nature

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or performance of the nuclear device whose yield is to be measured."[2] The Administration has also stated that the accuracy of the hydrodynamic method is relatively independent of the geologic medium provided only that measurements are made in the 'strong shock' region near the nuclear explosion, and expects that the method would provide yield estimates initially accurate to within a factor of 1.3 of the actual yield at the 95% confidence level, when applied at Soviet test sites to explosions with yields above 50 kt.[2] Apparently the Administration considers that an uncertainty of this size is acceptable and hence that the method would provide 'effective' verification of compliance with the TTBT and PNET.

This report summarizes information that is publicly available about the hydrodynamic method of yield estimation and uses this information to consider the strengths and weaknesses of this method for monitoring nuclear test bans.[3] Available, unclassified data as well as theoretical modeling show that the shock wave produced by an underground nuclear explosion propagates differently in different geologic media. As a result, accurately estimating the yield of an explosion from measurements of the radius of the shock front as a function of time generally speaking requires knowledge of the test geometry and the medium. However, the available data and theoretical modeling indicate that there is a relatively brief time during the outward propagation of the shock front when its motion is fairly insensitive to the nature of the medium, for those geologic media which have been studied. If this time is known, if data outside this interval are discarded in making the yield estimate, if the test geometry is known not to be a significant disturbing factor, and if the geologic medium in which the explosion takes place is one for which the U.S. has test data, the available evidence indicates that the yield can be estimated to within a factor of about 1.3 using the hydrodynamic method.

We therefore conclude that the hydrodynamic method could, if used in conjunction with other measurements that determine the nature of the geologic media and exclude possible disturbing factors, provide estimates of the yields of Soviet tests near the 150 kt threshold that are less uncertain than the seismic method currently used by the U.S. government. However, the factor of 1.3 uncertainty expected with the hydrodynamic method is only marginally smaller than the factor of 1.5 uncertainty thought by some experts to be achievable with the best remote seismic methods now available.

A key policy question raised by this study is whether attaching reservations to the TTBT and PNET to permit use of the hydrodynamic method to monitor tests near 150 kt is worthwhile, given possible disadvantages and the modest reduction in the uncertainty of yield estimates that may be expected.

YIELD ESTIMATION METHODS

Phases of a nuclear explosion deep underground. —In the following discussion it will be helpful to have in mind what happens when a nuclear charge is detonated deep underground. For present purposes the time development of the explosion may be divided into three phases (see note 4):

- First, the nuclear energy is released in less than a microsecond. This process is accompanied by emission of various types of nuclear radiation. The energy released produces a hot gas bubble in which the pressure and temperature rise steeply, reaching several million atmospheres and about a million degrees within a few microseconds.

- Second, the pressure of the hot gases in the bubble initiates a shock wave which moves away from the bubble in all directions at a speed that depends on the yield and is initially greater than the sound speed in the medium. The shock wave compresses the rock through which it travels. At this early time the shock wave is strong enough to completely crush the rock, causing it to behave like a fluid. This phase is therefore referred to as the 'hydrodynamic' phase. As the hot gases continue to expand, they create a cavity of substantial size, while the shock wave continues to propagate away into the surrounding medium. The hydrodynamic phase ends when the shock wave is no longer strong enough to cause the compressed rock to behave like a fluid.
- Third, the shock wave continues to propagate away from the cavity, at first crushing or fracturing much of the rock in the region it traverses but gradually decreasing in strength until it eventually becomes the leading wave of a train of seismic (elastic) waves, which propagate around and through the earth and may be observable thousands of miles away.

Radiochemical method.—This method of estimating the yield makes use of the effects of the nuclear radiation emitted during the first phase of the explosion on materials exposed to them. The radiochemical method is the most accurate one, but in addition to the yield it can also provide other information about the design and performance of the nuclear device that has been regarded as too sensitive to reveal to the Soviet Union. For this reason, it is usually considered inappropriate in the context of treaty verification.[5]

Hydrodynamic method.—In the hydrodynamic method of yield estimation, the radius of the front of the shock wave is measured as a function of time during the second, or hydrodynamic phase. Generally speaking, the larger the yield of the explosion, the larger the radius reached by the shock front a given time after the detonation. Thus, measurements of the radius of the shock front as a function of time, when combined with information on the nature and structure of the geologic media in which the explosion occurs and a model of the propagation of the shock wave through these media, may be used to estimate the yield of the explosion.[6–9]

CORRTEX is a particular technique for measuring the radius of the shock front as a function of time.[10,11] In this technique, an electrical cable is lowered into the hole in which the nuclear explosive is placed (the so-called *emplacement hole*) or into another hole drilled near the emplacement hole (a so-called *satellite hole*). When the expanding shock wave reaches the cable, the cable is crushed and electrically shorted. As the shock wave continues to expand, the point at which the cable is crushed moves quickly toward the surface. The way in which this point moves is measured by electronic equipment attached to the cable and located above ground. For TTBT verification purposes, the Administration is currently proposing placement of the sensing cable in a satellite hole or holes. With accurate knowledge of the location and orientation of the cable with respect to the emplacement hole, measurements of the point at which the cable has been crushed can be converted into estimates of the radius of the shock front as a function of time.

Seismic methods.—Seismic methods make use of measurements of ground motions caused by the elastic waves that propagate around and through the earth during the third stage of an underground nuclear explosion described above. Several recent reviews of these methods exist (see, for example, refs. 12–15) and so they will not be described further here.

Discussion.—It has been stated several times[16–19] in the context of TTBT and PNET verification that the hydrodynamic method is "direct" whereas seismic methods are not. From a scientific point of view there is no such distinction. All three methods discussed here involve production of a signal by the exploding device, propagation of that signal to locations more or less remote from the detonation point, and detection of the signal by sensors at those locations. Important questions are how the size of the signal varies with yield, how well the propagation of the signal is understood, and how accurately and precisely the sensors measure the signal. It has also been implied that use of the hydrodynamic method in and of itself eliminates bias and therefore the need for calibration. It does not. All three methods are subject to both bias and uncertainty. The issue is the actual or potential size of the bias and uncertainty likely to be encountered, and whether these are so large as to be of concern. The next section discusses the hydrodynamic method in more detail, including possible sources of bias and uncertainty in yield estimates made using this method.

HYDRODYNAMIC METHOD

There are three steps involved in using the hydrodynamic method to estimate yield. They are (1) determine the properties of the geologic media in which the explosion will take place, (2) measure the radius of the shock front as a function of time, and (3) estimate the yield of the explosion by fitting a model of the motion of the shock front to the sequence of measurements of the radius of the front.

Measurement of the shock radius.—Assuming that the geometry of the CORRTEX cable with respect to the detonation point and the time of detonation can be determined accurately, the CORRTEX equipment can provide a quite accurate measurement of the radius of the shock front as a function of time. Determining the geometry requires an accurate of survey of both the hole in which the CORRTEX cable is to be inserted and the hole in which the nuclear device is to be placed. The time of detonation is determined from the time of arrival of the electromagnetic pulse (EMP).[20] During a typical test, the CORRTEX equipment records the radius of the shock front at several thousand times.[10]

Modeling the motion of the shock front. —In order to derive a yield estimate from the radius of the shock front as a function of time, one must have a model of the propagation of the shock wave away from the detonation point. This propagation has been modeled in several ways. These include:

- Use of one- and two-dimensional hydrodynamic computer codes which numerically solve the fundamental conservation equations together with constitutive relations that describe the response of the geologic media to applied stresses.[21,22]
- Use of one-dimensional "similarity" solutions that incorporate the equation of state of the geologic medium.[3,7–9]
- Use of an empirical power-law formula whose parameters are estimated by fits to U.S. test experience.[6–9, 21]

No details were available to the author about the two-dimensional hydrodynamic computer codes and equations of state used to model ground shock propagation at Los Alamos[21] at the closing date for this report. Nor are any unclassified CORRTEX data currently available. Consequently the theoretical models described here are similarity solutions[3] based on published equations of state[7-9,23] while the test data mentioned are radius versus time measurements made using the so-called SLIFER method,[24] a shock radius measurement technique that was used prior to the CORRTEX technique.

Similarity solutions and SLIFER data.—The solutions discussed here make the following key assumptions: (1) the explosion is spherically symmetric; (2) the medium between the center of the explosion and the measuring cable or cables is homogeneous; (3) the shock wave is strong enough to crush the material through which it is propagating sufficiently to cause it to behave like a fluid; (4) the properties of the shocked medium are adequately described by a Hugoniot equation of the form $D = a + bU$, where D and U are the shock and particle velocities, respectively, and a and b are constants; and (5) the similarity assumption that the specific energy of the material just behind the shock front is a constant fraction of the mean specific energy of the material within the shocked region.[25] The Rankine-Hugoniot jump conditions across the shock front are of course satisfied. Despite their simplicity, these solutions agree well with the available SLIFER data, particularly if the phase changes that occur in some media at pressures below about 1 million times atmospheric pressure are taken into account.[3,7–9]

At early times, the shock wave is strong and the similarity solution is a self-similar blast wave.[3,7,8] During this phase the radius of the shock front depends on the density and equation of state of the medium and on the yield of the explosion. No unclassified test data on this phase are available. At moderately late times, the similarity solutions predict that the shock wave will propagate as a self-similar compressional wave in the (crushed and fluidized) medium. During this latter phase the motion of the shock front depends only on the so-called plastic wave speed[26] in the medium. Over a broad range of intermediate times, the similarity solutions are neither blast waves nor plastic waves. During this intermediate period the shock wave is only moderately strong, in the sense that the shock velocity is only a few times greater than the plastic wave speed, and hence the radius of the shock front depends not only on the density and equation of state of the medium and the yield, but also on the plastic wave speed in the medium. The similarity solutions appear to give a good description of SLIFER data, which are available at intermediate and moderately late times during the hydrodynamic phase.[3,7–9]

The similarity solutions and SLIFER data indicate that the shock wave produced by an explosion of given yield generally develops differently in different media. This is not surprising, since the density and plastic wave speed, for example, vary by factors of 1.6 and 3, respectively, for geologic media for which test data are publicly available.[7,8] As a result, the characteristic radius R where the shock wave produced by a 150 kt explosion changes from a blast wave to a plastic wave varies from about 100 feet in wet tuff to over 200 feet in dry alluvium. In basalt and granite, R is about 120–130 feet for this yield. Therefore, a yield estimate made by fitting a model of shock propagation to radius versus time measurements over a broad interval will generally be biased by any errors in the assumed properties of the medium. Similarly, unanticipated variations in the properties of a given type of rock, such as granite, within the deposit in which the explosion is detonated will introduce uncertainty in such a yield estimate.

However, for the geologic media for which test data are available (the dry alluvium, partially saturated tuff, saturated tuff, granite, basalt, and rhyolite at the test sites used) the density, equation of state, and plastic wave speed are correlated in such a way that there is a comparatively brief interval during the transition from blast wave to plastic wave when the radius of the shock front is relatively insensitive to the medium but relatively sensitive to the yield.[3,23] At present, this correlation does not appear to be well understood from any fundamental physical point of view. The time at which this "insensitive interval" occurs depends on the yield W of the explosion as $W^{1/3}$, varying from about 0.2 milliseconds after a 1 kt explosion to about 1 millisecond after a 150 kt explosion. Almost all of the test data on which this conclusion is based come from nuclear explosions at the Nevada Test Site. This conclusion is also reportedly supported by modeling.[22] If there are other relevant media whose properties are *not* correlated in this way, the insensitive interval does not exist. Thus, insensitivity to the medium can only be assured for materials that have been tested.

Los Alamos algorithm.—The algorithm used at Los Alamos to derive yields is to fit a power-law equation (the so-called Los Alamos formula) to CORRTEX data.[6–9,21] The formula is fit over the time interval from 0.1 to 0.6 milliseconds after detonation for an explosion with a yield of 1 kt, or 0.5 to 3.2 milliseconds for an explosion with a yield of 150 kt. These time intervals correspond to distances ranging from 6 to 16 feet from the detonation point for an explosion with a yield of 1 kt, or from 35 to 85 feet for an explosion with a yield of 150 kt. (Both times and distances are assumed to scale with W as $W^{1/3}$). They lie within the interval of insensitivity for media so far tested.[3] Over this interval, the Los Alamos formula as quoted in the literature[7–9] agrees with both the similarity solution and available SLIFER data to within a factor of about 2 (the published formula may not reflect current practice).

The Los Alamos formula is an empirical relation, *i.e.*, it is not derived from fundamental physical principles but is instead obtained by fitting a simple power-law expression to a collection of shock wave data. The formula must therefore be regarded as established only for those geologic media and pressure regimes where it has actually been verified. At distances less than the stated lower limit of validity, practical, operational, and engineering considerations make accurate measurements difficult. At still smaller distances the formula disagrees with the similarity solution. At distances greater than the stated upper limit of validity, the Los Alamos formula departs from the similarity solution and SLIFER data. At these distances the radius of the shock front is no longer insensitive to the medium.

In order to use the Los Alamos algorithm, the cable must sample the insensitive interval. In order to do this the cable must extend to within about 35 feet of the detonation point for a 150 kt explosion, or within 6 feet for a 1 kt explosion. Most of the data accumulated by the CORRTEX equipment are not within the insensitive interval. The shortest pulse interval possible with current CORRTEX equipment is 10 microseconds.[10] Thus, of the 2,000 or so radius measurements made during an explosion, all but about 40 must be discarded for an explosion with a yield of 1 kt, and all but about 200 for an explosion with a yield of 150 kt, in order to keep only data within the stated range of validity of the Los Alamos algorithm. Data from outside this range can of course provide additional information on the yield and a check on the consistency of the algorithm, if there is adequate knowledge of the geologic medium.

According to official statements,[1,2] the Los Alamos algorithm gives yields accurate to within a factor of 1.15 (at the 95% confidence level) of the yields given by the more accurate radiochemical method, for explosions with yields greater than 50 kt conducted at the Nevada Test Site. According to these same statements, the formula is expected to be accurate to within a factor of 1.3 at Soviet test sites. These statments are consistent with the results of the present study, provided that only data from within the region of insensitivity are used in the analysis, that the media in which Soviet tests take place are within U.S. experience, that possible effects which could interfere with CORRTEX measurements can be excluded, and that test geometries which would significantly disturb the shock wave from a spherically symmetric wave can be recognized and allowed for.

Factors affecting hydrodynamic yield estimates.—From the preceding discussion it is apparent that yield estimates made using the hydrodynamic method may be affected by a number of factors related to the geology of the test site and the geometry of the test. Factors that may introduce bias or increase uncertainty include:[6]

- Any errors in the survey used to establish the path of the CORRTEX cable relative to the emplacement hole, if the CORRTEX cable is placed in a satellite hole.
- Any properties of the nuclear device emplacement configuration or surrounding geologic media that cause the shock wave to propagate faster in one direction than another. The size of these effects is less for high-yield than for low-yield explosions.
- Emplacement of cables or other aspects of the test setup that cause other signals to interfere with measurement of the ground shock radius as a function of time.
- Any errors made in discarding data that are disturbed or are outside the insensitive interval and any errors in applying corrections to the data.

Although over 100 tests have been carried out with the CORRTEX sensing cable in the emplacement hole, experience using current CORRTEX equipment with the cable placed down a satellite hole is apparently limited (according to official statements, only four tests with this geometry have been carried out[2]). SLIFER data from satellite holes are available for several tens of earlier explosions.[22]

Possible requirements for establishing confidence in the precision of hydrodynamic yield estimates made at Soviet test sites.—Clearly, the more information that is available about the explosion and the nature of the geologic media in which it occurs and the more restrictions there are on the test geometry, the more accurate the hydrodynamic method will be. Some idea of the information that may be required to obtain uncertainties of a factor of 1.15 to 1.3 is provided by the Protocol to the PNET, which explicitly established the use of the hydrodynamic method as one of the monitoring methods that could be used for any explosion with a planned aggregate yield exceeding 150 kt. At the time the PNET was signed, the following information about the geologic medium was specified in the Treaty Protocol as needed to adequately verify the Treaty:[27]

- The type or types of rock and their physical properties, including density, seismic velocity, porosity, degree of liquid saturation, and rock strength

- Specific features of the geologic structure that could affect the yield estimation
- The length of the cannister containing the nuclear charge [and possibly containing diagnostic equipment, in the case of a weapon test], the dimensions of the tube or other device used to emplace the cannister, the cross-sectional dimensions of the emplacement hole, the nature of the materials (including their densities) used to fill the emplacement hole
- The configuration of any known voids with a volume greater than one cubic meter within the area

Measures specified to obtain this information included:

- Examination of rock core or rock fragments removed from the emplacement hole, and of any logs or drill core from exisiting exploratory holes
- A choice of one of several alternatives that include observation of construction of the emplacement hole, removal and examination of rock core or rock fragments from the wall of an existing exploratory hole, removal and examination of rock core or rock fragments from the wall of the emplacement hole, and construction of one or more new exploratory holes
- Observation of the emplacement of the explosive and confirmation of the depth of emplacement
- Observation of the stemming of the emplacment hole
- Continuous, unobstructed visual observation of the area of the entrance to the emplacement hole
- Photography of the exterior of facilities and installations associated with the conduct of the explosion

In addition, the Protocol placed specific limits on the dimensions of the cannister and required that tubes and conduits emerging from the emplacement point be filled with material of a density greater than a specified value. These measures were motivated by the requirement that the sensing cables be placed in the nuclear device emplacement hole. To ease many of the restrictive requirements of the PNET Protocol, it has been proposed that CORRTEX cables be placed in satellite holes for verification of weapon tests.

In order to provide assurance that the yield estimates derived from CORRTEX measurements are accurate for weapon tests and peaceful nuclear explosions near the 150 kt limit, Protocols specifying measures like these would be required.[28,29]

Relative intrusiveness.—The CORRTEX method is more intrusive than remote seismic methods for the following reasons:

- Personnel from the other country must be present at the test site before and during the test, and therefore have an extensive opportunity to observe test preparations. This would pose operational security problems.[30]
- Achievement of an uncertainty of a factor of 1.3 or less requires examination of the contents of the bore hole down which the CORRTEX cable is placed, and may require additional measurements and some constraints on test configurations (see above).

- The canister containing the nuclear device and any diagnostic equipment must be examined to verify that the conditions necessary for the yield estimate to be valid are satisfied. For tests of nuclear directed energy weapons, this examination could reveal sensitive design information unless special procedures are followed.[30]
- Achievement of confidence in the estimated yield may, for some test geometries, require placement of several sensing cables around the weapon emplacment point.
- Unless precautions are taken, the CORRTEX sensing cable and equipment could be affected by the electromagnetic pulse (EMP) generated by the explosion. Such precautions might be considered a hindrance in carrying out some tests. A detailed analysis of the EMP could reveal sensitive information about the design and performance of the nuclear device being tested. Therefore the electrical equipment used for yield estimation must be designed so that it does not acquire detailed EMP signatures.

Placing the sensing cable down the emplacement hole is relatively intrusive in weapon tests, since in this location it is more likely to collect sensitive information that could reveal the nature of the test. This problem would be alleviated if the sensing cable is placed in a satellite hole, as proposed for TTBT monitoring.

Use of the CORRTEX method to monitor low threshold or comprehensive test bans.—A question that has arisen repeatedly in discussions of CORRTEX is whether the method can be used at yields lower than 50 kt. Underground nuclear explosions as small as 1 kt produce shock waves that evolve in the same way as those produced by explosions of larger yield. At such yields, some engineering and operational problems are likely to be more difficult. For example, drilling a satellite hole within 6 feet of the emplacement hole to the depths of typical nuclear device emplacement, as would be required for use of CORRTEX to measure the yield of a 1 kt explosion, appears challenging. The need for such close placement would place restrictions on the size of the canisters used to contain the diagnostic instrumentation. Use of small canisters with diagnostic lines-of-sight to the detonation point could disturb the CORRTEX measurements, although placing the CORRTEX cable in a satellite hole should lessen such disturbances. Because the radii to be measured are much smaller, any survey errors become more important. Apparently the feasibility and desirability of using CORRTEX for monitoring a low threshold test ban treaty have not yet been carefully studied.

The CORRTEX method is not suited for detecting unannounced nuclear tests because it requires activity at the site in advance and the presence of monitoring personnel during the test. Because it is only sensitive to nuclear explosions that are very nearby, the method is also not suitable for monitoring a comprehensive test ban.

Comparison with remote seismic methods.—It may be helpful to compare the expected uncertainty of yield estimates made using CORRTEX with the expected uncertainty of yield estimates made using remote seismic methods. As mentioned in the Introduction, yield estimates based on seismic body wave magnitudes (the method currently used by the U.S. government) are considered to be uncertain by a factor of two at the 95% confidence level.[2]

However, at least two other remote seismic methods are available: a method based on measurement of surface waves and the so-called Lg method, which uses a wave guided in the continental crust. If both these additional methods are assumed to provide independent yield estimates that are, like those derived using the body wave method, uncertain by a factor of two at the 95% confidence leve, yield estimates obtained by combining all three remote seismic methods would be uncertain by a factor of 1.5 at the 95% confidence level.[31,32] (The actual uncertainty could well turn out to be less than this, since the uncertainty of yields estimated using the Lg method alone has been reported as a factor of 1.3 at the 95% confidence level when the method is used for explosions with yields near 150 kt.[33])

This uncertainty of a factor of 1.5 expected by some experts is only marginally larger than the uncertainty of a factor of 1.3 which the Administration expects from use of the CORRTEX method. Some experts think that the surface-wave and Lg methods could significantly reduce the uncertainty of seismic yield estimates even if measurements are made only outside the Soviet Union (some of these measurements would be at so-called "teleseismic" distances of thousands of miles whereas others could be at so-called "regional" distances). At large distances, uncertainties in the attenuation of Lg waves become more important. For this reason, measurements at regional distances would be advantageous. If many stations at regional distances are thought necessary, this would require modification of the TTBT and PNET.

CONCLUSIONS

In the present report we have reviewed information that is publicly available about hydrodynamic yield estimation methods and CORRTEX measuring equipment, and have considered the strengths and weaknesses of this approach for monitoring nuclear test bans. Our key conclusions are as follows:

- The hydrodynamic method and CORRTEX equipment could, if used in conjunction with other measurements and some restrictions on test designs, provide estimates of the yields of Soviet tests near the 150 kt threshold with an uncertainty of about a factor of 1.3 for test media within U.S. experience.
- The feasibility of using the hydrodynamic method and CORRTEX to monitor a threshold test ban treaty with a threshold substantially less than 150 kt has not yet been studied carefully. There are engineering and operational difficulties that may be expected in using the method to monitor a low threshold test ban and that need to be examined in a verification context.
- The hydrodynamic method is not suited for detecting unannounced nuclear tests, or for monitoring a comprehensive test ban agreement.
- The uncertainty of a factor of 1.3 at the 95% confidence level expected for the hydrodynamic method and CORRTEX is only marginally smaller than that thought to be achievable with the best remote seismic methods now available, which according to some experts are expected to have an uncertainty of a factor of 1.5 or less at this same confidence level.

A key policy question raised by this study is whether attaching reservations to the TTBT and PNET to permit use of the hydrodynamic method to monitor tests near 150 kt is worthwhile, given possible disadvantages and the modest reduction in the uncertainty of yield estimates that may be expected.

It is a pleasure to thank G. S. Miller for help in computing similarity solutions and for numerous helpful discussions of yield estimation using the hydrodynamic method.

NOTES

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2. *Verifying Nuclear Testing Limitations: Possible U.S.–Soviet Cooperation* (U.S. Department of State Special Report No. 152, August 14, 1986).
3. A more detailed technical report is in preparation.
4. S. Glasstone and P. J. Dolan, *The Effects of Nuclear Weapons* (U.S. Government Printing Office, Washington, D.C., 1977), pp. 61-62 and 238.
5. W.K.H. Panofsky, testimony before the Senate Committee on Foreign Relations, January 15, 1987.
6. J. T. Rambo, *Rep. UCID–17292* (Lawrence Livermore National Laboratory, Livermore, California, 1976).
7. M. Heusinkveld, *Rep. UCRL-52648* (Lawrence Livermore National Laboratory, Livermore, California, 1979).
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11. Los Alamos National Laboratory public information sheet on CORRTEX (April 1986).
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13. W. J. Hannon, *Science*, **227**, 251 (1985).
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16. H. A. Holmes, testimony before the Senate Committee on Foreign Relations, January 13, 1987.
17. J. H. McNally, testimony before the Senate Committee on Foreign Relations, January 13, 1987.
18. R. B. Barker, testimony before the Senate Committee on Foreign Relations, January 13, 1987.
19. D. A. Vesser, testimony before the Senate Committee on Foreign Relations, January 13, 1987.
20. R. A. Jefferies, private communication.
21. D. D. Eilers, *Mem. P-15-87-U-37* (Los Alamos National Laboratory, January 28, 1987).
22. R. E. Hill, *Mem. P-15-87-U-69* (Los Alamos National Laboratory, February 10, 1987). According to this memorandum, the two-deminensional code used is the code SOIL available commercially from Computer Code Consultants, Inc., 400 10*th* Avenue, N.W., Chisholm, MN 55719. The formulation of this code has reportedly been described in W. E. Johnson, *TOIL (A Two-Material Version of the OIL Code)* (General Atomic Report GAMD-8073, 1967), W. E. Johnson, *Code Correlation Study* (Air Force Weapons Laboratory, Report AFWL TR 70-144, April, 1971), and *Dynamic Response of Materials to Intense Impulse Loading* (P. C. Chou and A. K. Hopkins, eds., Air Force Materials Laboratory, 1977).
23. W. R. Perret and R. C. Bass, *Rep. SAND 74-0252* (Sandia Corp., Albuquerque, New Mexico, 1975).
24. M. Heusinkveld and F. Holzer, *Rev. Sci. Instrum.*, **35**, 1105 (1964).
25. These solutions are not fully self-similar. In a fully self-similar shock wave the distributions with radius of the flow variables, such as the pressure and density, evolve with time in such a way that only their scales and the radius of the shock front change, while the shape of the distributions remains unaltered (see L. I. Sedov, *Similarity and Dimensional Methods in Mechanics* (Academic Press, New York, 1959 [English Translation]). For such motions, assumption (5) is automatically satisfied. Moreover, all the scales have a power-law (or, occasionally, exponential) dependence on time. As discussed below, the solutions referred to here are fully self-similar only early, when they are blast waves, and at late times, when they are plastic waves. Furthermore, the fraction referred to in assumption (5) is expected to be different for the early and late motions and hence not constant. Thus, for the solutions discussed here assumption (5) must be regarded as an approximation.

26. See Ya. B. Zel'dovich and Yu. P. Raizer, *Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena* (Academic Press, New York, 1967 [English Translation]).
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28. S. S. Hecker, testimony before the Senate Committee on Foreign Relations, January 15, 1987.
29. M. D. Nordyke, testimony before the Senate Committee on Foreign Relations, January 15, 1987.
30. R. E. Batzel, testimony before the Senate Committee on Foreign Relations, January 15, 1987.
31. R. Alewein, as quoted in the Minutes of the November 4-5, 1985, meeting of the Committee on Seismology of the National Research Council Board on Earth Sciences.
32. P. G. Richards, testimony before the Senate Committee on Foreign Relations, January 15, 1987.
33. O. W. Nuttli, *J. Geophys. Res.*, **91**, 2137 (1986).

NR
DC

Natural Resources
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January 30, 1987

The Honorable Claiborne Pell
Chairman
Senate Foreign Relations Committee
U.S. Senate
Washington, DC 20510

Dear Senator Pell:

I am writing to provide you with my views regarding proposals for ratification of the TTBT and PNET. While I have had extensive discussions with Soviet officials associated with the joint NRDC/Soviet Academy of Sciences test ban verification project, at the onset let me make it clear that these are entirely my own views. I have not asked for, or received, Soviet opinions on this issue.

I agree with Dr. Panofsky and Mr. Colby that the preferred option is to ratify the TTBT and PNET without reservations. Unfortunately, this option does not appear to be politically feasible at this time. I tend to agree with those who believe that there are only two realistic alternatives: do nothing; or accept something close to the Administration's proposed language. I do not believe doing nothing is a good option. Rather, it is in the U.S. interest to achieve Senate ratification of these treaties now so that we can move quickly towards a Comprehensive Test Ban Treaty. On the other hand, a major problem with the Administration's formulation stems from the fact that in open testimony before the Committee and in public statements, the Administration has not been forthcoming regarding severe limitations of the CORRTEX technique. Considerable additional information related to the geology of the test site and the geometry of the nuclear device and its emplacement relative to the CORRTEX device, is necessary to achieve the accuracy being ascribed to the CORRTEX system. Obtaining this information will be very intrusive and it may not be obtainable for Soviet tests. Thus, it is premature to suggest that CORRTEX offers any advantages over teleseismic measurements supplemented by measurements using incountry (regional) seismic monitoring stations. Thus it would be a tragic mistake to tie the President's hands in negotiating additional agreements with respect to CORRTEX. If CORRTEX measurements are desirable at all it may be that only one or two calibration tests would suffice.

One or two calibration tests would clearly be less intrusive than the Administration's proposal.

A viable compromise may be for the Senate to accept the Administration's language but interpret "all appropriate nuclear detonations" to give this or a future President maximum flexibility in ascribing the number of "direct accurate yield measurements" required, including as few as one calibration test. Moreover, the Senate should interpret the "additional agreements" called for under the Administration's proposed language to include the possibility of clarifying the language of the TTBT Protocol under Section 1d. In so doing it would avoid the appearance that the Senate is requiring that the Treaty be renegotiated. Clearly, support for this legislative approach must be conditioned on a careful vote count to insure that destructive amendments can be turned back.

I hope these comments are helpful as you wrestle with this difficult and critical issue.

Respectfully,

Thomas B. Cochran
Senior Staff Scientist

Responses of Dr. Siegfried S. Hecker to Questions Asked by Senator Helms

VERIFICATION

Questions 1.: How involved are the national labs in developing verification technology? How involved are you in actually monitoring Soviet compliance with existing techniques?

Answer: During the 1958-61 Moratorium on testing, Los Alamos designed the only ground-based detection system for explosions in space, which soon was deployed to monitor the 1963 Limited Test Ban Treaty. Los Alamos and Sandia together have for over 20 years conceived, designed, fabricated, and delivered the satellite-based instrumentation that monitors the earth's atmosphere and outer space for LTBT compliance. Many instruments used to monitor the Non-Proliferation Treaty (NPT) were designed, and all IAEA inspectors are trained, at Los Alamos. The proposal to limit individual peaceful nuclear explosions to the TTBT limit of 150 kt originated at Los Alamos. We provided the analytical means to do this reliably using data obtained with existing equipment developed by LLNL and Sandia. Los Alamos provided the technical input that guided the phase of the PNET negotiations involving on-site hydrodynamic measurements. Since then we have greatly refined the necessary analysis and developed, jointly with a contractor, a vastly improved kind of equipment, known as CORRTEX, for the verification measurement. We are developing two promising non-seismic techniques that might distinguish between small earthquakes and low-yield underground nuclear explosions from 1000s of kilometers distance. We have explored several methods to detect and estimate than CORRTEX. Research directed to monitoring directed energy activities and to detection of nuclear materials on earth and in space is in progress. Relatively small programs at Los Alamos study seismic technologies; LLNL is very much more heavily involved in this particular field. Our work in verification technology continues with highest laboratory priority and could be productively expanded.

At present, actual monitoring funcitons are performed by other agencies. We have provided analyses of the results of data-collection by these other agencies and of the effectiveness of a variety verification procedures.

Question 2.: Verification and compliance judgement are policy decisions made by the Administration which require considerable technical background. How involved have the labs been in supplying information to the Administration, in this regard?

Answer: Los Alamos has been very involved in supplying technical information and analysis to several Administrations. We have provided analyses of the Soviet test patterns during the period since the TTBT limit took effect and of the ability of various alternative methods to achieve effective verification of Soviet compliance. We have provided the basic verification concept (direct hydrodynamic yield measurements) and now are responsible for the technology (CORRTEX) that has been selected by the President as the basis for negotiations with the Soviets for improved TTBT verification. We also have been active with regard to LTBT and NPT verification issues.

Question 3.: This Administration has set standards for "effective verification" which are higher that the "adequate verification" which previous administrations found acceptable. In you view, has this stiffening of verificaiton standards been justified?

Answer: The U.S. defined "adequate verification" officially in the mid-70s, in connection with a possible Comprehensive Test Ban. My own view is that verification of compliance with the TTBT and PNET is neither effective nor adequate if either side can obtain a significant military advantage through clandestine violation that cannot be overcome by the other side without violating the treatics. This is equivalent to the earlier definition, applied to the treatics now under review. At present, TTBT verification does not meet this standard. The fundamental issues therefore is: How can we effectively verify Soviet compliance in the future? I do not believe verificaiton can be considered adequate unless it is effective; this underlying principle does not seem to me to have changed significantly in the last decade or more. We may understand now better than in the past what is required for verification to be effective and, therefore, we are more aware of present verification shortcomings.

Question 4.: Please describe how CORRTEX was developed and applied to verification.

Answer: Hydrodynamic yields have been a fundamental tool in the nuclear weapons program since Trinity. For atmospheric shots, fireball picutres provided the yield techniques to underground tests, using equipment known as SLIFER. The technology then was used extensively in teh underground test program by both weapons labs, and the underlying theory was thoroughly studied and extended. When it was recognized that individual yields of explosives in multiple peaceful explosions, required by the Soviets, must be limited to the TTBT limit, Los Alamos took the lead in adapting SLIFER to this job. We also provided technical guidance to the PNET negotiating team. In 1975, one of the Los Alamos diagnostic groups tried a new approach to the measurement of hydrodynamic shock position, based on a proven technology called time domain reflectormetry. That approach became the basis for CORRTEX, which in the last 10 years has undergone extensive refinement and field testing. Today, fourth-generation CORRTEX equipment is used routinely on most U.S. tests, and it is ready for deployment for verification of both PNET and TTBT compliance.

Question 5.:	The Administration has said that CORRTEX could monitor Soviet nuclear tests with an error margin of 30%. Do you agree? Has this effectiveness been demonstrated and tested?
Answer:	For our own tests, where we know all details of the geology and the emplacement geometry, CORRTEX has been much better than 30%. The 30% figure is our estimate based on allowance for less detailed information in a verification situation. We believe it is conservative; in most cases we expect to do better. For the majority of tests, we believe a standard test geometry can be defined that will not interfere with test objectives while providing high assurance of a successful verification measurement. In some few non-standard cases, similar to ones already investigated theorectically as well as experimentally by both weapons laboratories, special arrangements will be needed. Our experts understand these requirements, and have thus far dealt with all such situations successfully. I should point out that verification of compliance with the 150 kt limit is a limited and practical objective. It is not necessary to measure every yield to 30% with 95% confidence. It is only necessary to have that accuracy when the yield is near the threshold to assure with the desired confidence that the limit has not been significantly exceeded. A requirement for similar accuracy at yields well under the threshold might serve purposes other than strict verification, but they have not been our primary objective.
Question 6.:	How many seimologists do you have working at the national labs?
Answer:	Los Alamos has 88 people with degrees in geology or geophysics. I would estimate that about 10% of these are seismologists.

Question 7: The Administration has said that the margin of error in measuring Soviet tests using currently available seismic techniques is 100%. Do you agree?

Answer: The teleseismic yield estimate commonly is stated to be uncertain by a factor of 2 at a 95% confidence level. That is, a Soviet test whose estimated yield is 300 kilotons is said to lie between 150 kt and 600 kt with 95% confidence. Since this uncertainty first was attributed to teleseismic yield estimates, always at the 95% confidence level, actually official estimates of the yields of Soviet tests have retroactively been reduced several times; by now the cumulative reduction near the TTBT limit is almost a factor of 5. More important today than the exact value of the uncertainty factor is the fact that the size of the uncertainty factor itself is not an adequate guide to the effectiveness of verification, because it does not describe a limit placed on a would-be violator. The question that must be answered for any contemplated verification method is: if this method is used, how large must an actual Soviet test yield be before we are reasonably likely to obtain a signal that leads to confident identification of violation? It is only at this yield level that we might expect violations to be deterred and compliance to be enforced by the method in question? Experience and anlysis both have demonstrated that with seismic techniques, the deterrence-level yield is well in excess of twice the threshold limit. Thus the nominal "factor of two" is very misleading.

Question 8.: Please describe how varying geophysical characteristics affect teleseismic monitoring.

Answer: The seismic community recently has focused most of its attention on the assumption of a reduced attenuating effect in the transmission path from the Soviet test site as compared with the sites where yields are known to us, leading to the concept of "bias." While the bias argument is plausible, it is not based on actual yield information, and as noted earlier the bias estimate has been changed several times. Recent studies at Los Alamos suggest that other very localized geophysical factors, such as residual porosity, may be of equal or greater importance than attenuation in the earth's mantle.

Question 9.: If you are able to get verifiable geophysical data and calibrated instruments, what level of accuracy do you believe could be achieved with teleseismic monitoring?

Answer: As indicated above, I believe the appropriate answer to this question involves the estimated yield at which the Soviets could occasionally test without serious concern about our reaction, rather than a hypothetical uncertainty factor. Verified geophysical data would be of some value. The seismic instrumentation itself is well calibrated; what usually is meant by calibration of the seismic method is calibration of the transmission path by on-site measurement of Soviet test yields with CORRTEX so that the "bias" is experimentally determined. We are currently not convinced that a single value of bias can be determined or that this "calibration" is likely to result in sufficient reduction in the test yields available to the Soviets to constitute effective verification.

Question 10.: Dr. Lynn Sykes of Columbia University has said that the margin of error for teleseismic monitoring is only 30%. How do you account for this difference of opinion? How could the dispute among scientists be resolved?

Answer: To the best of our understanding, the value of 30% stated by Sykes is a one-sigma value, corresponding to about a 68% confidence level. The factor of 2, or 100%, is a two-sigma, or 95% confidence factor would be 1.6, rather than 2. Even so, the Soviets could exceed the threshold to a degree that I would consider to be militarily significant. However, acceptance of this factor seems unlikely. The best way to resolve the dispute in my opinion is by routine on-site observations of the kinds proposed by the President. After a number of years of this, assuming the Soviets cooperate, the issue will be resolved.

Question 11.: Do you believe that the Soviets could deceive the CORRTEX system by decoupling?

Answer: While nothing is impossible, we believe that there is very little chance of their successfully doing so. Decoupling of the explosive energy from its surroundings with a large cavity is a known evasion technique for seismic verification, and a similar attempt in principle shock position, where the main effect might be a large asymmetry in the explanding of a cavity of reasonable size would be clearly revealed in the CORRTEX data obtained. In addition, any such attempt will almost certainly be disclosed by the inspection and logging procedures to be provided in a new technical annex to the TTBT Protocol.

WEAPONS DESIGN

Question 1.: In accordance with customary international law, the United States has observed the TTBT for 12 years. What effect has this had on U.S. weapons programs?

Answer: As described in my written statement at the hearings, a number of nuclear tests have been precluded by the TTBT limit that almost certainly would have been carried out otherwise. Among these were full-yield tests of new or modified high-yield designs based on older tested technology, as well as full-yield stockpile confidence tests. In particular, full-yield tests for the Peacekeeper and Trident II missiles have not been possible. We have maintained a high level of confidence in these weapons by making their designs very conservative, based on tested concepts and components. The penalties have been tradeoffs in weight, range, and yield compared to optimized designs. Development of new high-yield technology has, of course, been curtailed. Nevertheless, we have been able to meet requirements for new high-yield weapons during the past 12 years because of our inventory of tested designs.

Looking toward the future, however, it is becoming clear that certain weapon requirements now under study by the DOD and the DOE laboratories may well prove to be beyond the reach of the older tested design technologies. These prospective requirements are determines in most cases by the changing nature of the threat and the targets, e.g., hardened, dispersed or relocatable targets that must be held at risk if stable deterrence is to continue.

An additional effect of the TTBT limit on U.S. weapons programs is that only a handful of designers that have taken principal design responsibility for a test over 150 kilotons remain in the thermonuclear design groups at the weapons laboratories.

Question 2.: Assuming the Soviet Union is similarly bound, what effects do you think a 150 kiloton threshold has on stability between the U.S. and the Soviet Union?

Answer: The Soviets historically have deployed a higher proportion of high-yield weapons than the United States, although their average yields have appeared to be decreasing in recent years. It is reasonable to assume that their high-yield test needs already have been more extensively addressed than those of the United States, where a decade or more of general yield reductions recently had to be reversed in response to Soviet actions. As a result, we have found it necessary to stockpile several high-yield systems since 1976 without the benefit of full-yield testing. Thus, evin if complete compliance with the TTBT limit can be assumed, the effect might be significantly to the advantage of the Soviets.

On the other hand, the major impetus behis the President's drive for better verification is the clear possibility that the Soviets have not been similarly bound, and more importantly cannont be in the future. The yields at which they could occasionally test, should a need arise, are levels at which tests would be of significant military value to the United States, but which we cannot do. In addition to problems related to the present stockpile that such tests could resolve, they could be used to significantly increase the military capability of present systems or to achieve major economies in Special Nuclear Materials should this become necessary. In addition, tests in the range of yields available to the Soviets but not to the United States could be used to explore new regimes in weapons physics and advanced concepts that might have a significant long-range effect on stability.

Question 3.: Do you see any trend in Soviet military programs which warrant U.S. programs requiring tests above 150 kilotons?

Answers: As I pointed out in my statement at the hearings, all testing restirctions have an associated technical risk. U.S. policymakers must balance the risks against the potential benefits.

From a technical standpoint only, there would be a significant benefit from occasional tests above the 150 kt limit. They would allow us to test some of the most important current strategic weapons systems at full yield. Also, they would allow us to respond better to some future requirements for high-yield weapons that are being brought about by an aggressive Soviet program to bury and harden targets that the U.S. military consider necessary to hold at risk in order to maintain a stable deterrent. In the answer to the previous questions I have alluded to other potential benefits from such tests.

Question 4.: With the current 100% margin of error in monitoring, the Soviets could test up to 300 kilotons before we could be sure they had exceeded the 150 kiloton threshold. The Adminstration proposes to reduce the error margin to 30% which means the Soviets could test up to 195 kilotons before we could know they had violated the threshold. What, if anything, of military significance can they gain by testing in the 195 - 300 kiloton range? If they could gain, what effects would such gains have on U.S. security?

Answer: As I already have noted, the quoted uncertainty factor is a misleading guide to the effectiveness of verification. The Soviets now would have to test at well above twice the TTBT limit before we would feel confident that they had violated the threshold. This is demonstrated by our failure to respond with more than a diplomatic not to a Soviet test in 1980 having an estimated yield at that time of 316 kt. The note, of course, was rejected by the Soviets. Thus, we cannot now deny the Soviets the ability to test int he 300 - 450 kt range if we use only seismic verification. This would permit full-yield tests of new designs in this yield range, which appears to be of increasing importance to the Soviets and to the United States. Such designs could have higher yield-to-weight ratios than our planners now anticipate from their estimates of Soviet technology. The result could be higher yields, greater missile ranges or greater payload fractionation with MIRVs having counter-silo capability. The U.S. military is best qualified to address how these Soviet advantages might affect U.S. security.

In addition, if the Soviets have the ability to extrapolate test yields by a factor of about two, as we now have for certain well-understood designs, the ability to test in the

300 - 450 kt range could affect Soviet ability to deploy weapons of 600 - 900 kt, a range of great military significance. The result could be new Soviet systems with unexpectedly high yields.

Finally, with such test yields available, at least occasionally, the Soviets could explore entirely new design technologies that are foreclosed to the United States. The result could be a significant adverse technological surprise. I should add that the nominal figure of 195 kt as applied to CORRTEX verification may be misleading in the opposite direction, that is, the resulting verification capability may be more effective than this figure implies. We believe that a U.S. presence at the Soviet test site will serve as a significant deterrent to violations of any kind beyond simple design errors, which are allowed for in the understanding between the two sides.

Question 5.:	From the point of view of design or verification, is 150 kilotons a logical threshold or is it an arbitrary level set by negotiators?
Answer:	The 150 kiloton level was arrived at by negotiation between the U.S. and Soviet delegations. It does not correspond to any clearly defined "break point" in nuclear technology. From the point of view of verification, the potential for asymmetry adverse to U.S. security would be more severe at lower thresholds, where such break points become a significant factor.

Question 6.: Some have argued that we should pursue further limitation on testing such as a yearly quota on the number of tests or thresholds below 150 kilotons. Please evaluate the ideas.

Answer: To date, we have been able to meet military requirement under the TTBT restriction. We would not be able to say this if the yield limit had been significantly lower. In my written statement I describe the trend toward increased yields for new strategic systems over the past 10 years because of Soviet actions. A reduced threshold would seriously impair our ability to perform critical tests while the other finds it possible to continue those it finds to be essential. This situration easily could result from a significantly reduced threshold, leading to a major asymmetry we were powerless to relieve short of treaty withdrawal.

Let me address the questions of a yearly quota on the number of tests. In effect, we already have yearly quotas on U.S. tests imposed by the budget considerations, available manpower, and logistics. A quota treaty with the Soviets would entail more complex verification issues even than verification of the TTBT and PNET. One example would be the question whether the quota applied to events, which might involve several devices fired simultaneously, or individual weapon tests. Arguments can be made for either approach, although from verification of compliance with a quota limit below some relatively low threshold; should the number of such tests be unlimited? I believe that the quota idea should be approached with great caution.

Finally, it should be ver clear that additional restrictions on testing significantly increase the technical and military risks to the United States. In my view, they will be justified only when sufficient progress has been made in arms control to stabilize the military requirements for effective deterrence, and in the political relationship with the Soviet Union to reduce our dependence on a deterrence policy. Policymakers must look hard at what demonstrable benefits accrue from additional testing restrictions that may have very high costs.

Responses of William E. Colby to Questions Asked by Senator Helms

> 1. When you were Director of the CIA, how much effort did the Intelligence Community apply to monitoring Soviet compliance with arms control agreements?

The period 1973-1976 followed shortly after the first comprehensive arms controls agreements of SALT I and the ABM Treaty. The Intelligence Community mobilized a major effort to follow Soviet actions to determine whether they complied with those agreements. This included tasking various collection resources to monitor Soviet test facilities, operational sites and and other related locations, plus general searches for possible new areas or activities which might raise questions under the agreements. The Community also participated in Executive Branch committees to provide intelligence products and analysis to support Administration actions and deliberations with respect to these questions, for example the American delegation to the Standing Consultative Commission and a special subcommittee of the National Security Council which addressed arms control issues. Unclassified evidence of these efforts can be seem in the report issued during the Carter Administration discussing compliance questions which had arisen over the previous years. This activity supplemented the normal intelligence coverage of Soviet military activities, of course, which provided much of the base for these particular efforts on arms control.

> 2. How involved was the Intelligence Community in formulating arms control positions?

At the working level members of the Intelligence Community maintained contact with appropriate officers in the departments and agencies considering arms control matters. The Agency also participated formally in the various interdepartmental groups and committees which considered arms control questions. By tradition, the Agency did not take a position with respect to these and other policy questions but it did express judgments on the verifiability of various proposals under consideration, and it did offer estimates with respect to the actions and programs of the Soviet Union with respect to such matters.

3. This Administration has set standards for "effective verification" which are higher than the "adequate verification" which previous administrations found acceptable. In your view, has this stiffening of verification standards been justified?

No. The earlier phrase was defined in Senate hearings as requiring that "any Soviet cheating which would pose a significant military risk or affect the strategic balance would be detected by our intelligence in time for the United States to respond effectively". It obviously is designed to protect our nation against any Soviet action which could threaten it. The new phrase was defined in the latest Arms Control Impact Statement (for FY 87, dated April 1986) as that which would "enable the United States to know with confidence whether the terms of agreements are being honored". On its face, this would seems to require knowledge of every Soviet action which would not honor the treaty, however minor and of little or no consequence to the United States. The definition goes on, however, to say that "In practice, this means the United States must have the ability to acquire sufficient information to render a reasonable judgment on whether other parties are complying with the terms of an agreement and to render this judgment in a timely manner, such that we can respond appropriately, including compensating for any risk posed to our security by possible violations."

This additional language certainly "includes" the protective purpose of the first definition, but plainly goes much further in demanding that the United States have positive knowledge of whether the Soviets are "complying" with the agreement, rather than only of violations. The definition does not explain how this positive assurance is to be obtained in practical terms, but surely the Administration would take agreement with its new definition by the Congress as a license to demand far more intrusive verification arrangements than the identication of violations would require. In legal terms, the definition demands that innocence be proved, not violation - a very different standard. Since I believe that our monitoring capabilities currently provide us sufficient coverage to protect our nation against surprise or cheating in this field (and in fact have done so), and the two treaties under consideration provide additional cooperative measures to facilitate better monitoring, I can only assume that insistence on the additional and unnecessary scope of verification in this new definition will make the treaties non-negotiable, and deprive our nation of the very real benefits they can provide to our security.

Responses of Milo D. Nordyke to Questions Asked by Senator Helms

Question 1: Disagreements still exists regarding methods for calculating Soviet yields. What information or analytical work would resolve these differences

1. As indicated in my testimony, virtually all seismic studies that have been done indicate the presence of a significant difference in the transmission qualities of the upper-mantle and crust of the earth beneath the U. S. and Soviet test sites. This difference results in the seismic signals from a given yield test at the Soviet test site looking over twice as large as the seismic signal from the same yield test at the U. S. test site. However, there are some observers that reject the overwhelming seismic evidence and in fact seismology itself as a means to determine Soviet yields and prefer to cite several non-seismic seismic studies that indicate that there is no bias at all and that seismic yield estimates for Soviet yields are factors of 2-3 too small. Unfortunately, neither side can point to unequivocal data to support their view. It is precisely because of this major disagreement that I believe that, as a minimum enhancement measure, the U. S. should require an agreement that provides for the confirmation of the yield of the two calibration tests in each geophysically distinct area as called for in the TTBT Protocol. Because the differences in viewpoint regarding the value of the estimates of Soviet yields are so great, having verified yields for these calibration yields would confirm or deny the existence of the seismic bias.

Question 2: One area of disagreement discussed in the NYT indicated that some scientists argue that seismic techniques with access to the test site and surrounding areas with in-country seismic stations and verification of the yields of calibration explosions would be more effective than the administration proposal calling for hydrodynamic yield measurement on all tests with yields above 75 kt. Would you comment on this argument?

2. The implementation of an agreement to verify the yields of a number of calibration explosions and to deploy in-country seismic stations around each country's test sites would significantly reduce both the uncertainty in the bias and the random uncertainty and thereby reduce concerns about possible Soviet violations. These two measures would not, however be as effective as measuring yields of every Soviet nuclear test with a planned yield above 75 kt with hydrodynamic means as proposed by the administration. By the same token, it should be made clear that the impact on the U. S. nuclear test program of the calibration and in-country seismic station option would be significantly less than the impact of the hydrodynamic yield option.

Question 3: There are clear differences among scientists about whether the Soviet have violated their obligations under the TTBT, about what the accuracy of current monitoring techniques are, and about what monitoring techniques to apply in the future. Do you agree that existence of these disputes weakens confidence in the agreements and that better verification should be sought, if only to quiet these disputes?

3. No matter how elaborate or extensive a treaty verification regime is, there will always be questions raised about compliance by those who disagree with the fundamental goals of the treaty or agreement. In reality, a treaty is a contract with hundreds of explicit and implicit provisions, some of which are fundamental to national security and others that are trivial. Monitoring compliance with the terms of a treaty generally involves either assuring the absence of banned items or, as in the case of the TTBT, the counting or measuirng of limited items. The bans will have linguistic or syntactic ambiguities. Counting or measuring systems will have errors and uncertainties which can be exploited. It is obviously very desireable to write treaties with a view towards minimizing the ambiguities, errors and uncertainties so as to limit opportunities for cheating as well as concerns of cheating. In the end, judgements have to be made on balancing the complexities of the language, the intrusiveness of the verification regime, and the national security risks of cheating

and of having no treaty at all. But even if the most elaborate verification regime could be realized, no one should be deluded into thinking that there would be not controversy regarding compliance.

With specific regard to the TTBT, as elaborated in my testimony I believe it contains a number of critical, unverifiable provisions--namely the exchange of unverified yields for two "calibration" tests from each geophysically distinct testing area and unverified geophysical data about the test sites. As indicated in my answer to the first question, I believe that negotiation of an agreement that provides for verification with on-site hydrodynamic verification of the yields of those two tests in each area together with the geological data that would be collected in conjunction with such an on-site measurements would provide the data needed to eliminate the most serious disagreements about Soviet compliance with the TTBT. It would not eliminate all disagreements.

Responses of Paul G. Richards to Questions Asked by Senator Helms

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Q. Many scientists have applied considerable time and resources to the question of monitoring Soviet nuclear tests, but disagreements still exist. What sort of information or analytical work would resolve these differences?

A. It is my opinion that on technical issues relevant to verifying the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET), the community of technical experts is in agreement on the following main items:

(i) seismic yield estimates for the largest Soviet explosions during 1976-1985 can be supplied with an uncertainty that is less than a factor of two;

(ii) an outcome of research in seismology in the last ten years, is that modern methods of seismic yield estimation are more accurate than those available in 1974, which, at that time, were deemed acceptable for "effective verification" for the more important of the two treaties (the TTBT);

(iii) when other National Technical Means for yield estimation have been reviewed, the seismic method has been deemed the best method.

Thus, I conclude that such disagreements as do exist, on technical issues, are of a minor nature within the expert community. For example, there is some disagreement on whether the factor of uncertainty for seismic yield estimates is 1.7 or 1.5. (For an explosion estimated as having a central value yield of 150 kilotons, a factor of uncertainty of 1.7 means that there is a 95% probability of the actual yield lying in the range 88 - 255 kilotons. A factor of uncertainty of 1.5 means that the range is 100 - 225. These ranges are not very different.)

There is no possibility that such minor disagreements will be resolved to the satisfaction of every person working on the problem. Until there is a clearer definition of the phrase "effective verification", it is impossible to know if the remaining areas of minor technical disagreement have significance.

There is also an area of disagreement on the question of whether CORRTEX should become a required technology for purposes of yield estimation, in addition to the seismic methods. This debate can hardly be addressed within the technical community until the desired standards of accuracy are openly known. Thus, weighing seismology against CORRTEX (when the latter is possibly more accurate, and certainly more intrusive and perhaps impossible to negotiate) has become essentially a political judgement, not one based on technical requirements.

Q. One of these differences among scientists within government was recently reported in the NY Times. Some argue that seismic techniques, epecially if there is access to the test sites and surrounding areas to permit calibration, would be more effective than the Administration's proposed use of CORRTEX. Please comment on this discussion.

A. It is relevant to note that when the seismic method is applied to estimate the yields of our own nuclear test explosions in Nevada, the resulting seismic yield estimates are quite accurate. That is, they have accuracy about equal to that currently claimed for the CORRTEX method as proposed for use on Soviet test sites. (This has been described as having the ability to estimate yields to within plus or minus about 30%, i.e. a "factor of uncertainty" equal to about 1.3. That such accuracy is attainable with the seismic method in Nevada is apparent from a scientific paper by Otto Nuttli published in the Journal of Geophysical Research, February 10, 1986. One sigma for the data points that determine Nuttli's calibration curve for Nevada is about 0.05 seismic magnitude units, translating to about a 30% error in yield, near 150 kilotons, at the 95% confidence level.)

In practice one may presume that it is easier for us to get relevant information about the Nevada site, to enable the seismic method to be used accurately, than to get information about Soviet sites, although from a purely scientific perspective this presumption is hard to evaluate. I am prepared to believe that CORRTEX-based yield estimates (if they can be negotiated) may be slightly more accurate for Soviet explosions in the range 75 - 150 kilotons. But it will not be clear that this would result in "effective verification" until this phrase is better defined for the technical community.

Q. There are clearly differences among scientists about whether the Soviets have violated their obligations, about the accuracy of current monitoring techniques, and about what monitoring techniques to apply in the future. Do you agree that the existence of these disputes weakens confidence in agreements, and that better verification should be sought, if only to quiet the disputes?

A. I do not believe there are serious differences between well-informed scientists on the basic question of yield estimation for the largest Soviet explosions. Spokesmen for all three DoE weapons laboratories have testified to the effect that there is no technical basis for asserting non-compliance by the Soviets. Thus, I believe current disputes are basically in the political arena, not the technical arena. I do not believe it makes sense, from a technical standpoint, to seek "better verification" until we know what the standard of "effective verification" is. If the latter standard were clarified, then (since there is general agreement on the accuracy of different yield-estimation technologies) we would know whether or not "better verification" is required.

I do not agree that "better verification" should be sought merely to quieten disputes. To do so would allow a person armed only with a technically poor argument, but who is contentious and wilfully ignorant, to wield an effective veto over negotiations.

However, disputes should not be ignored. They arise largely because the seismic and non-seismic methods of yield estimation are criticized or wrongly used by agency spokesmen and/or scientists who are not familiar with relevant technical details. Examples are (a) the frequent characterization of seismic yield estimates as "possibly wrong by a factor of two", and (b) the presumption in some quarters that Soviet non-compliance with a 150 kiloton threshold can immediately be deduced from the occasional occurrence of well-based yield estimates that are indeed above 150. There are continuing needs for a forum in which the technical issues are subjected to critical review; and for dissemination of accurate information on the basic technical issues, including the nature of measurement uncertainty, in order to support well-informed policy debates.

Responses of Dr. Roger E. Batzel to Questions Asked by Senator Kerry

Question 1. You cited the first reason for continued nuclear testing as maintaining the proper functioning of the stockpile of weapons we currently have.

Of the warheads that have been thoroughly tested before being put into the stockpile, what percentage have shown subsequent problem requiring nuclear testing?

How many times have warheads been taken "as is" from the stockpile, subjected to a stimulated stockpile-to-target sequence, and exploded? Has this ever been done?

Question 2. In dealing with the issue of stockpile confidence, you stated that testing is required "to both find problems and to assess the adequacy of fixes which are implemented," and specified that one-third of all modern weapon designs place in the stockpile have required and received postdeployment nuclear tests for resolution of problems.

What is a stockpile confidence or stockpile reliability test?

What percentage of nuclear tests conducted by the U.S. since 1975 have been undertaken solely for stockpile confidence or reliability?

Answer to Questions 1 and 2:

1. The phase "thoroughly tested" is misleading. It is simply impossible in the real world to test the nuclear weapon designs certified by the Laboratories under all foreseeable Stockpile-to-Target (STS) conditions including adverse storage or delivery environments, the latter including expected defensive threat level and changing targets. It also is not possible to know or foresee all future safety and security requirements at the time weapons enter the stockpile. Safety criteria (e.g., one-point safety, safety against accidental HE detonation resulting in SNM dispersion, intrinsic radiation) and security requirement can and do change. Expected threat levels or other STS parameters change as the Soviets acquire new capabilities. The acceptability or availability of certain materials originally used in weapon fabrication may change as a result of factors entirely beyond the control of the weapon scientists. Finally, it may discovered, sometimes in the course of subsequent related testing, that design errors were made, or even that basic physical data used in earlier designs is significantly in error. Thus, the term "thoroughly tested" requires qualifications at best, and validated designer judgment is essential, both in determining what tests are essential at the time of certification and in evaluating problems that may arise later.

In specific response to your question, 14 of 41 weapons designs in stockpile, since 1958 or 34 percent of the weapons, have required postdevelopment nuclear tests to fix the designs, In three-fourths of these cases, the problems were discovered as the result of nuclear tests, and additional tests were required to confirm that the "fix" was satisfactory. These weapons were thought to be "thoroughly tested" when they entered the stockpile.

Regarding stockpile confidence tests, every test we do helps maintain our confidence in the stockpile, because we are testing component types used in existing weapons. Most tests serve several purposes, For example, a DNA effects test often uses a stockpile weapon component (e.g., a primary), thereby serving to test our confidence in that component. Also, we routinely do production verification tests on new systems, where we take a weapon out of stockpile after it has been exposed to operational conditions for some time and test it. In other tests, we may be verifying a fix that was made to a stockpile problem. Then there are actual confidence tests which are done to test our confidence of weapons that have been in the stockpile for a number of years. Since 1975, Lawrence Livermore National Laboratory and Los Alamos National Laboratory have done 18 tests Deleted which fall into the category of stockpile confidence tests either in whole or in part. Table 1 lists these tests

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Stockpile confidence test are not necessarily just proof tests, they are nuclear systems tests. The degree of stockpile-to-target simulation varies with the technical requirements of the delivery system, and is limited by budgetary and safety considerations. Some functions may be stimulated in stockpile confidence tests; others may be omitted. For example, warhead electrical systems are not immediately compatible with the complex electrical control systems required for safety and diagnostics of nuclear testing. Hence some electrical modification is required for nuclear confidence testing. The Threshold Test Ban Treaty (TTBT) yield limit may also require changes so that the yield will not exceed 150 kt.

In only one test in history, FRIGATE BIRD in 1962 (prior to the Limited Test Ban Treaty (LTBT), did we do a complete STS confidence test which involved firing a Polaris missile from a submarine and detonating the nuclear warhead in the atmosphere near Johnston Island. Even that test did not expose the Polaris warhead to a nuclear environment,

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To reemphasize, all of our nuclear tests contribute to stockpile confidence, and a few are solely for this purpose. This is not unlike rocket or cruise missile testing. The ability of the rocket designer to assess small engineering changes is developed not by testing the conservative design about to be, or already in, the stockpile, but rather by extending the bounds of his experience into new realms or beyond the old "margin".

Table 1. Stockpile Confidence Related Tests Since 1979

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Question 3. From a scientific point of view, it is technically more difficult to test a nuclear weapon at reduced yield, or at its full certified yield? Are additional uncertainties involved in conducting reduced yield tests? Is so, what are they?

Question 4. If a weapon has performed satisfactorily at a reduced yield, would you have high confidence that it would perform at higher yields?

Answer to Questions 3 and 4:

The calculations which support a full yield test or a partial yield test are essentially the same. However, if a test is conducted at full yield, there is little ambiguity about the performance. Extrapolation from a partial yield test to a full yield configuration does introduce uncertainty in the full yield performance. This uncertainty is larger as the ratio of full yield to partial yield test gets larger.

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Question 5.

It is my understanding that our strategic weapons have two stages, a fission primary stage that triggers a secondary fusion stage. Dr. Richard Wagner has testified before the House Armed Services Committee as follows. "Fortunately, for those warheads that are in our arsenal today, which if tested would exceed the threshold, we believe we have an adequate history of testing prior to the Threshold Test Ban Treaty. Moreover, we can test, for example, the primary or a combination of the primary and an altered secondary, which would not exceed the threshold. The primary design is a sort a bellweather of whether it (a nulcear warhead) will "work." Do you agree with this statement? If not, please specify your reasons for disagreement. If Dr. Wagner's statement is true, would you agree that the 150 kt threshold does not impair our confidence that warheads with higher yields will perform correctly?

Answer to Question 5:

I substantially agree with Dr. Wagner's statement. For systems in the stockpile, the 150 kt limit does not impair our confidence that the warheads with higher yields will perform correctly. However, see my answer to Question 8 for a qualifying remark.

Question 6. Do you believe the U.S. can assure the reliability of existing nuclear weapons by conducting reduced yields tests of strategic primaries? If not, why not?

Question 7. Would a 5 kt threshold be adequate to allow you to conduct stockpile reliability and safety tests? If not, why not? Under such threshold limit, would it be possible to conduct reduced yield tests of strategic primaries?

Answer to Questions 6 and 7:

Under a 5 kt threshold, we could not assure the reliability of U.S. strategic weapons.

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We could conduct safety tests under a 5 kt limit.

Question 8. This Committee has heard testimony indicating that U.S. voluntary compliance with the 150 kt threshold has led to increased uncertainties regarding the performance of U.S. nuclear weapons whose full yield is higher that the 150 kt threshold. Do you agree with this assessment?

Answer to Question 8:

I do not agree with the statement. However, if we had made observations during our routine stockpile surveillance programs that signaled a potential problem in the thermonuclear stage of one of our very high yield systems (1 mt or greater), the 150 kt limit may have limited us. We have observed no such problems to date, and have experienced no such limitation. This does not preclude, however, a problem from arising in the future where the 150 kt limit will place a limitation.

Question 9. Dr. Donald M. Kerr, in testimony before the Senate Armed Services Committee, stated the following: "The nuclear designs for MX, Trident II (D-5), and Minuteman III (MK-12A) were developed and tested at their full yield prior to the imposition of the 150 kt TTBT limitation. Their stockpile certification is, or will be based on that hearing."

To your knowledge, is Dr. Kerr's statement accurate?

Can those designs today be tested adequately within the 150 kt limitation through reduced yield testing?

Are you confident that these high yield weapons will work? If not, please specify why not.

Answer to Question 9:

Yes, to all three questions.

Question 10. The New York Times has reported that the CIA believes the Administration's current proposals for verifying nuclear testing agreement's are "deficient" and fail to "meet the tests of comprehensiveness and technical soundness." Would you agree or disagree with this assessment?

Answer to Question 10:

I am not familiar with the Central Intelligence Agency's report referred to in the New York Times article describing the Administration proposals as "deficient" and failing to "meet the tests of comprehensive and technical soundness." I believe the Administrative proposals for enhanced verification of the TTBT are complete and fully cover all significant concerns regarding possible Soviet evasion of the TTBT yield limit.

Question 11. The Committee has received testimony from Pentagon and Energy Department witnesses expressing strong support for safeguards that include "a vigorous verification program and continued emphasis on intelligence activities." In the past, you have testified that you believed the area of test ban verification was being underfunded. Do you still believe this to be the case? How much additional funding is needed, if any, and in what areas?

Answer to Question 11:

There are a number of areas where increased funding for verification research would be beneficial. The seven major areas we would currently propose are as follows:

1. Development and Evaluation of On-Site Yield Estimation Techniques for Tests in the 5-50 kt yield range.

Deleted A variety of techniques including CORRTEX and others such as surface ground motion measurements and regional seismic phases need to be evaluated for their accuracy as treaty verification methods. We estimate this project could be accomplished in two years at a cost of $5M each year.

2. Development of Prototype Equipment for a Deployable Seismic Verification Systems (DSVA)

A proposal is currently before DOE to develop the DSVS for both test site and country-wide monitoring. In the test site mode, the DSVS would consist of approximately five stations surrounding the site and would be primarily used for yield determination. In country-wide monitoring, the DSVS would be used to monitor decoupled, clandestine tests and consist of up to 30 stations depending on the treaty to be verified. The current proposal is for the production of single three-component stations that are sensitive to the frequency range of 0.1 to 40 Hz. The DSVS should also include arrays in the event it is necessary to monitor a 1 kt TTBT or a Comprehensive Test Ban Treaty (CTBT) and a suitable facility and appropriate procedures for routine data reduction should be established. Costs for the five station DSVS data center and associated supporting seismic research is estimated to be $11M in the first year, $12M the second year, and $8M the third year. This system will be ready for deployment in FY90. Costs for including arrays would add $12M in the second year and $18M in the third and fourth years.

3. Feasibility Study and Site Survey for Field Test of Seismic Decoupling

Cavity decoupling to reduce seismic signals is a significant evasion challenge in monitoring a CTBT or low-yield LYTTBT. The U.S. has only one full-scale test for decoupling. It was of limited value because of its small yield and the limited data recording capabilities. Although we have had numerical modeling and laboratory experiments, a full-scale test with appropriate high-frequency instruments will be required to fully answer questions and resolve many of uncertainties with respect to decoupling using non-spherical cavities. We estimate that a feasibility study could be completed and a plan developed in about a year at a cost of $2M. The execution of the full-scale experiment, assuming a suitable site could be found, would take several years and would cost in excess of $20M.

4. Field Experiment and Laboratory Studies to Better Understand Seismic Coupling at Soviet Test Sites

In order to reduce the uncertainty in estimating Soviet yields, we propose a dedicated nuclear explosion in an area of the Nevada Test Site in which the geologic materials differ significantly from those encountered in standard U.S. tests and are as much like those encountered at the Soviet test sites as possible. This explosion together with associated measurements to characterize the material properties and geologic structure, combined with laboratory studies to accurately model the explosion source in a new environment. This project will draw upon the results of an initial DARPA effort in this area and take two years to complete at a cost of about $7M.

5. Laboratory and Calculational Studies to Develop Methods for Discriminating Between Chemical and Nuclear Explosions

This experiment will involve recording data from a detonation of large, contained chemical explosions near a nuclear explosion of roughly the same size as the largest chemical explosion. By using the same receiver sites and similar source to receiver paths, any difference in the signals can be attributed to the difference in sources.

Combining the seismic observations with calculational and laboratory modeling we will attempt to determine if there is a basis for discrimination between chemical and nuclear explosions. This project would take two years to complete and would cost about $10M assuming that a suitable nuclear explosion in the on-going test program could be used for the nuclear source.

6. Development of CTBT On-Site Inspection (OSI) Technologies and Equipment

CTBT On-Site Inspection technologies involve a wide variety of techniques including radiological sampling, deployment of a local seismic net, and geological and geophysical surveys, These techniques need to be evaluated and demonstrated and equipment procured before a CTBT is negotiated if the treaty term are to permit effective OSIs. We estimate this project could be accomplished in three years at a cost of $7M the first year and $10M the second, and third years.

7. Development of a Structure Approach to Test Ban Monitoring and Compliance Evaluation

Negotiating and verifying compliance with test ban treaties require the development and implementation of frameworks which take into account:

1. Monitoring information and constraints available from all sources.
2. The statistical uncertainties of the monitoring information.
3. The variations in the value judgments of the decision-makers
4. The military significance of various types of violations.
5. The deterrence value of a well-constructed verification system.

Although the details of the frameworks will vary from treaty to treaty, the general categories listed above are applicable to all. Also, some details of the frameworks will be common to all.

Isolated elements of such a structured analysis can be made available for TTBT compliance evaluation in a matter of weeks. A comprehensive study which includes lower yield thresholds, quotas and the CTBT could require two years at a cost of $2M/year for a total cost of $4M. Individual elements can be scheduled and budgeted to address high priority negotiating or compliance evaluation issues. An on-going cost of $200-300K/year should be budgeted to allow the inclusion of new data and evaluation of the effects of changes in the international climate on the value judgements involved.

Responses of Dr. Siegfried S. Hecker to Questions Asked by Senator Kerry

Q1. In your testimony, you stated that the TTBT limits have affected a significant fraction of nuclear tests since March 31, 1976, limiting the value of these tests.

Since that date, of the warheads that have been thoroughly tested before being put into the stockpile, what percentage have shown subsequent problems requiring nuclear testing?

How many times have warheads been taken "as is" from the stockpile, subjected to a simulated stockpile-to-target sequence, and exploded? Has this ever been done?

What percentage of nuclear tests conducted by the U.S. since March 31, 1976 have been undertaken solely for stockpile confidence or reliability?

A1. The phrase "thoroughly tested" can be misleading. We cannot, of course, test statistically significant numbers of any given design; the various costs involved would be prohibitive. Hence, we must make the best use of every test we do to assure confidence in the present and future stockpiles and to provide benchmarks for the nuclear weapon designers. It is impossible, in addition, to test the weapon designs certified by the Laboratories under all imaginable Stockpile-to-Target (STS) conditions. Choices must be made among those that are considered most likely to affect weapon performance. Typical problems requiring test decisions include anticipated adverse storage or delivery environments. The latter are affected by expected defensive levels and changing targets. The term "thoroughly tested" thus requires qualification at best, and validated judgments by the nuclear weapon designers are essential, both in determining what tests are necessary before initial certification, and in evaluating problems that may arise later.

Conditions affecting confidence may change significantly during the weapon's stockpile life. It should be noted that a single major problem discovered by testing of one weapon design can raise serious reliability questions about other designs that can only be answered by further testing of those designs.

Historically, one-third of all of the modern weapon designs have required post deployment testing to resolve critical confidence issues, and in three-fourths of these cases an unsuspected problem could only have been discovered, or a suspected problem could only have been demonstrated, by nuclear tests.

Nine new weapon designs have been certified by the two weapons laboratories since March 31, 1976: B61-3, -4, -5; W76; W78; W79; W80; B83; W84; W85; and W87. All were thoroughly tested. Since its initial deployment, however, a further test of the W79 has been required. A nuclear test after the start of production revealed a serious problem with the W80 design that could not be identified in non-nuclear laboratory tests. The problem required further testing to correct as well as to determine whether other problems existed. This experience made it necessary to perform similar tests on the W84. In addition, a nuclear stockpile confidence test of the W84 revealed another problem. In this case the problem disclosed by a nuclear test was resolved without further nuclear testing. The B61-4 also required a test after deployment in order to restore full confidence in its performance under all STS conditions. Thus post-production or -deployment testing was essential to restoring or maintaining confidence in the reliability of four out of nine new designs. In addition, an earlier design, the W68, had developed an aging problem that required rebuilding with different materials and components, and the new version required nuclear testing.

Before the restriction to underground testing in 1963, it was possible to take a few weapons through the entire STS and test their full-yield performance. Since 1963 this has rarely been possible. Since 1976, it has been even more difficult because of the TTBT limit.

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When necessary, the nuclear test involves modifications of the stockpile weapon in order to comply with the TTBT limit.

In the period from April, 1976 through the present, there were 161 announced nuclear tests. Of these, only 13 were specifically identified as stockpile confidence tests (under a joint DOD/DOE Memorandum of Understanding). This number, however, does not adequately reflect the number of tests that were directly related to stockpile confidence or reliability. For example, there were 14 effects tests in this period; such tests are vital to confidence in stockpile and weapon-system performance. Moreover, many additional tests during this period were specifically related to reliability and long-term stockpile confidence issues; some of these explored the most important range of STS conditions, as mentioned above, and as already noted, a few revealed serious problems that required further tests of one or several other weapon designs. In total, more than one-third of all of the tests in this period had stockpile confidence issues as a principal objective (in some cases, other objectives were accomplished as well).

Finally, while confidence in the stockpile depends directly on the tests mentioned here, it also depends indirectly on the results of all of the tests, since they contribute essential data that calibrate and validate the judgments of the weapon designers. Ultimately, it is confidence in those judgments as they are applied to day-to-day stockpile issues that is the basis for confidence in the U.S. nuclear arsenal.

Q2. From a scientific point of view, it is technically more difficult to test a nuclear weapon at a reduced yield, or at its full certified yield? Are additional uncertainties involved in conducting reduced yield tests: if so, what are they?

A2. A test at reduced yield may well be more complex, and its interpretation will of necessity be more complex, than one at full yield, Unquestionably, it is technically more difficult to certify weapons tested only at partial yield. If the weapon is tested at full yield, it still is necessary to assess the possible effects of differences between the test environment and the STS environment corresponding to the test conditions (and other STS environments not duplicated in the full-yield test), and of possible deviations of production weapons from the test devices. All of these things require expert designer judgment based on test experience. If, in addition, major components, usually the thermonuclear ones, must be modified in a significant way to meet yield limitations, we clearly are dealing with an even more complex problem, in which the physics of the design can be affected severely. Reliance on designer judgment now becomes even more critical, in a situation in which the validity of that judgment cannot be fully tested experimentally. In some cases, this must be allowed for when a yield uncertainty is specified. Finally, our ability to extrapolate from partial yields with confidence is limited; larger extrapolations than we are able to base on past test experience carry a level of risk that we and the military would consider unacceptable.

Q3. If a weapon has performed satisfactorily at a reduced yield, do you have good confidence that it would perform at higher yields?

A3. Some uncertainty always is involved when extrapolating yields. The degree of uncertainty depends on the specific test and the means that must be used to reduce the yield for the test. To date, we have extrapolated on the basis of previous test confidence. The necessity to extrapolate yields will present more of a problem in the future, as we get farther and farther away from that previous test experience. It would be particularly difficult if we needed to consider new, previously untested, designs in order to meet new military requirements. It is possible in such cases to make mistakes that are catastrophic, involving total failure rather than imprecise prediction of the higher yield. We must avoid such situations.

Q4. It is my understanding that our strategic weapons have two stages, a fission primary stage that triggers a secondary fusion stage. Dr. Richard Wagner has testified before the House Armed Services Committee as follows. "Fortunately, for those warheads that are in our arsenal today, which if tested would exceed the Threshold, we believe we have an adequate history of testing prior to the Threshold Test Ban Treaty. Moreover, we can test, for example, the primary or a combination of the primary and an altered secondary, which would not exceed the Threshold. The primary design is a sort of bellwether of whether it [a nuclear warhead] will work." Do you agree with this statement? If not, please specify your reasons for disagreement. If Dr. Wagner's statement is true, would you agree that the 150 kiloton threshold does not impair our confidence that warheads with higher yields will perform correctly?

A4. Dr. Wagner's first statement is true by design, not by accident or coincidence. We specifically have been able to design systems so that we have been able to rely on design concepts and components already tested at full yield. This has resulted in more conservative, and in some cases less advantageous, designs than would be the case if we were able to test at full yield.

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Thus, under the 150 kt limit, we have intentionally designed conservatively so that we use previously tested designs that can be extrapolated with sufficient confidence to justify certification. While this has allowed us to meet DOD requirements thus far, we may not be able to do so in the future. Furthermore, if the threshold limit had been substantially lower than 150 kt, we could not have made the necessary extrapolations with confidence during the past 10 years.

Q5. Do you believe the U.S. can assure the reliability of existing nuclear weapons by conducting reduced yield tests of strategic primaries. If not, why not?

A5. I do not. Primaries simply cannot be tested reliably at reduced yields. All of our testing experience points to the fact that primaries must be tested as close to the final product, and its environment, as possible. Much of the uncertainty in nuclear weapon performance is associated with an inadequate knowledge of the fundamental physics of primary behavior. Thus, the design of boosted primaries remains an empirical science. We simply have no experimental data base to justify any optimism that tests at reduced primary yields can provide confidence in full yield primary performance. What little information we have points in the opposite direction.

Q6. Would a five kiloton threshold be adequate to allow you to conduct stockpile reliability and safety tests? If not, why not? Under such a threshold limit, would it be possible to conduct reduced yield tests of strategic primaries?

A6.

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Q7. Dr. Donald M. Kerr, in testimony before the Senate Armed Services Committee, stated the following: "The nuclear designs for MX, Trident II

(D-5), and Minuteman II (sic) (Mk-12A) were developed and tested at their full yield prior to the imposition of the 150 kiloton TTBT limitation. Their stockpile certification is, or will be based on that testing."

To your knowledge, is Dr. Kerr's statement accurate?

Can those designs today be tested adequately within the 150 kiloton limitations through reduced yield testing?

Are you confident that these high yield weapons will work? If not, please specify why not.

A7. I am confident that these weapons will work, although the basis for their certification differs in a fundamental way from that of weapons tested at full yield in weaponized production form. I outlined some of these differences in my answer to Questions 2 and 3. In the case of the W78 warhead for the Mk-12A, a full-yield test was accomplished before the TTBT limit, but necessary deviations of the production weapon from the test device led to concerns about certification that were resolved only with considerable difficulty. A partial yield confidence test has validated the judgments made at that time. The other two weapons mentioned both are based on a single full yield test of their thermonuclear component. Deleted

Deleted Tests very near the TTBT limit have been absolutely essential during development of the present designs for MX and Trident II, and we are confident that these weapons will perform well. However, both are conservative designs based on previously tested technology. If the TTBT limit had been much lower, the present designs for these systems could not have been developed, and other approaches would have been necessary that involved significant penalties.

Q8. The New York Times has reported that the CIA believes the Administration's current proposals for verifying nuclear testing agreements are "deficient" and fail to "meet the tests of comprehensiveness and technical soundness." Would you agree or disagree with its assessment?

A8. I assume you refer to verification of compliance with the TTBT and the PNET. I believe that the current Administration proposals are not deficient; in contrast, they are sufficient to provide effective verification of the treaties. The physical principles involved are well established and confirmed by experiment. The instrumentation involved has reached a high state of development. There is extensive experience on which to base the technical details that must be settled in negotiations. The technology on which the President bases his proposal thus rests on a strong foundation of scientific research, engineering development and practical field experience. I disagree with the assessment reported by the New York Times.

Q9. The Committee has received testimony from Pentagon and Energy Department witnesses expressing strong support for safeguards that include "a vigorous verification program and continued emphasis on intelligence activities." Do you believe verification is being underfunded? How much additional funding is needed, if any, and in what areas?

A9. Los Alamos has, together with our colleagues from Sandia National Laboratories, been responsible for conception, design, fabrication and delivery of the satellite instrumentation that monitors Earth's atmosphere and outer space for compliance with the limited test ban treaty; these responsibilities and committments have been honored for over two decades. Recently, greatly expanded activities have been necessary relating to the CORRTEX hydrodynamic-yield measurement technology that supports enhanced verification of the TTBT and the PNET.

Our highest verification priorities, the satellite instrumentation and CORRTEX activities, have strained available resources at the expense of other research and development programs that are directed to an increased verification capability for the future.

The President is committed to continued discussions on test limitation in parallel with significant progress in arms control, once the TTBT and PNET are ratified. Any additional restrictions on testing must be verifiable; it is our judgment that now is the time to start further work in this area. Our specific proposals have been submitted to the Department of Energy.

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